Prospects of Sustainable Land Management amidst Interlocking Challenges in the Upper Beshillo Catchments, Northeastern Highlands of Ethiopia

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Declaration

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Abbreviations

Abbreviation	Stands for
ANRS	Amhara National Regional State
ANOVA	Analysis of Variance
ASTER	Advanced Space-borne Thermal Emission and Reflection Radiometer
CSA	Central Statistical Authority
DAs	Development Agents
DEM	Digital Elevation Model
DFID	Department for International Development
DPSIR	Driving Force-Pressure-State-Impact-Response
EMA	Ethiopian mapping agency
ERDAS	Earth Resources Data Analysis System
EthioSIS	Ethiopia Soil Information System
ETM	Enhanced Thematic Mapped
FAO	Food and Agriculture Organization of the United Nations
FDRE	Federal Democratic Republic of Ethiopia
FDREPSC	Federal Democratic Republic of Ethiopia Population Census Commission
FESLM	Framework for the Evaluation of Sustainable Land Management
FGD	Focus Group Discussion
EROS	Earth Resources Observation Systems
FGD	Focus Group Discussion
GCPs	Ground Control Points
GoE	Government of Ethiopia
GPS	Global Positioning System
GDP	Gross Domestic Product
GIS	Geographical Information Systems
GTP	Growth and Transformation Plan
Ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
ITCZ	Inter Tropical Convergence Zone
IWM	Integrated Watershed Management
KII	Key Informant Interview
LULC	Land Use and Land Cover
m.a.s.l	Mean Above Sea Level

MERET	Managing Environmental Resources to Enable Transition to More Sustainable Livelihoods
MoA	Ministry of Agriculture
MoWR	Ministry of Water Resources
MoARD	Ministry of Agriculture and rural Development
NPC	National Planning Commission
NMA	National Meteorological Agency
PASDEP	Plan for Accelerated and Sustainable Development to End Poverty
PSNP	Productive Safety Net Program
USGS	United States Geological Survey
REDD+	Reducing Emissions from Deforestation and forest Degradation, plus the sustainable management of forests, and the conservation and enhancement of forest carbon stocks
RUSLE	Revised Universal Soil Loss Equation
SLF	Sustainable Livelihoods Framework
SLM	Sustainable Land Management
SPSS	Statistical Package for the Social Sciences
SRTM	Shuttle Radar Topography Mission
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Program
USGS	United State Geological Survey
UTM	Universal Transverse Mercator
WCED	World Commission on Environment and Development
WGS	World Geodetic System
WOCAT	World Overview of Conservation Approaches and Technologies

Abstract

Land degradation is a great threat to the Beshlo Catchment in Blue Nile Basisn, not merely as an environmental issue, but also a social and economic problem. In Gedalas Watershed (one of the micro catchments of Beshelo), land degradation, mediated by both biophysical and socio-economic drivers, is among the major environmental sustainability *and social-economic development threats in the area. The threat is manifested in depletion of natural vegetations, water, soil and other natural resources; disruption of ecosystem functions, processes, integrity, and services. Given its particular vulnerability, watershed management activities have been in operation since the mid-1970s. Recently, the idea of Sustainable land management through integrated watershed development program has been initiated with the objective of reducing land degradation risks and ensuring food security at both the nationwide and family circle. Despite these investments and efforts, real evidences of success and failures of such efforts were not satisfactory explored. The objectives of this study were, therefore, to analyze the existing status and future prospects of sustainable land management and evaluates its implication on the environmental integrities and the local livelihoods specific to Gedalas watershed. For this effect, the study investigated the dynamics, deriving forces and implications of LULC, soil erosion and soil fertility status of the watershed, current status of watershed management practices, pertinent challenges and opportunities for practicing land management technologies and approaches that might help meet the sustainability requirements of SLM practices. In addition, the study explored factors that determine the willingness of farming households to undertake SLM practice. As the study carried in the coupled human-environment system of rural landscapes, interdisciplinary geographical approaches which integrats social and natural science methodologies were employed to deal with issues of land degradation-and-rehabilitation status comprehensively. The general findings of the study show that though it would be dificult to measure all the composite aspects of land degradation, some of the parameters considered in this study revealed that land degradation is a perpetuating challenge in the watershed. It is evidenced from the overall undesirable land use/cover changes i.e transition of 21.25% of Afro/sub alpine landscapes, 17.59% of the grasslands and 8% of shrub lands to either to cultivated land or settlement areas over the 1973–2017 period, which have unintended negative socio-ecological repercussions on the watershed; high annual mean soil loss value (which range from 37t/ha/year average values to 393 t/ha/yr soil loss rates on water courses) that exceed threshold level and a wide gap between the need for SLM and the actual achievement of SLM practices,including limited adherence to the idea behind contemporary land management policies and implementation principles and approaches. The study further revealed the presence of opportunities as well as a myriad of challenges that need to be tackled in order to achieve sustainable land management goals. The study colcludes that, though, some encouraging progresses have been observed in the SLM project sites; land degradation has remained a problem in the watershed. This calls for strenuous efforts to promote and assist wide scale adoption of SLM practices that address the pervasive land degradation problem and achieve land degradation neutrality as highlighted in sustainable development goals.*

Keywords: *Land degradation, Soil erosion, LULC, LULC change, RUSLE, SLM, Livelihood, Upper Beshillo watershed, Ethiopia*

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Dedication

I dedicate my PhD thesis to my late father **Yimam Yesuph & elder brothe Amare G/Egzabher,** who passed away recently. This dedication is a symbol of gratitude for their concern, love, and support during my all academic journey. I will never forget you. I can imagine your happiness, had you been alive.

Rest your soul in Peace!

CHAPTER ONE

1 INTRODUCTION

1.1 Background of the Sudy

Land is one of the precious limited natural resources for most agriculturally based countries of the world both in economic and social terms. Nonetheless, its inherent production potential is under pressure due to a variety of natural and manmade factors (Barrow, 2006; Blanco and Lal, 2010; Andersson et al., 2011; Woldu et al, 2020). Land degradation has detrimental impacts on agricultural productivity and on the overall ecological functions that ultimately affect rural livelihoods[1] and living standards (Bewket, 2007; Moges and Holden, 2007; Vågen et al, 2013; Gebreselassie et al, 2016). A noted from the literatures, land degradation trim down the productive capacity of many agricultural lands worldwide (UNCCD, 2015). Land degradation is a global problem that affects both developing and high-income countries (Nkonya et al., 2016). However, its impact is greater in poorer countries, where agricultural activity is crucial to the development and the livelihoods of the majority of the population (Barbier and Bishop, 1995; Mekuria et all, 2018).

Land degradation can be manifested by land productivity reduction, physical loss of soil, gradual change in the characteristics of topography, decline in land resources' resilience potential from effects climate change and variability, alteration of hydrologic regimes, increased sediment loading of water bodies, reduced carrying capacity of pastures, depletion of vegetative cover and deterioration of the overall ecological functions of the area (Foster, 2006; Bai et al., 2008; ELD Initiative, 2013; Temesgen *et al.,* 2014).

Although Ethiopian highlands are relatively better endowed with agricultural land and potentials, these critical natural resources have been in a state of serious process of land degradation for many years. Land degradation is one of the principal ecological and economic problems that affect agriculture, which is crucial to the development and basis of livelihood. This, in turn, has contributed to the low or stagnant agricultural productivity (Zeleke et al., 2006, Amsalu, 2006, Tamene et al., 2014).

Evidence from the existing empirical literature reveals that land degradation induced by both biophysical and socioeconomic factors. The most vital biophysical factors that provoke land degradation include topography, detrimental land use/cover change, inherent soil erodiblity and recurrent drought. Many socioeconomic and policy related factors such as population pressure (although debates on population-environment-nexus is not yet concluded), poverty, excessive grazing and deforestation, limited access to rural credits and local markets, inadequate technical support, insecure land tenure

[1] In this research, rural livelihoods stands for natural resources based activities and choices that human being make in order to to secure their well-being and continually assured their existences, so long as there is an effective management of these resources

arrangements and general policy and legal environments are the underlying deriving factors which trigger the proximate causes of land degradation (Bekele and Drake, 2003; Amsalu, 2006; Bantider et al., 2011).

While, the governments of Ethiopia in collaboration with variety of international donor agencies and NGOs has long recognized the importance of environmental sustainability issues as one of the development agenda of the country and have made strenuous efforts to control and reverse land degradation for decades, the extent to which environmental degradation has declined or unabated is not well assessed in the study area, as population pressure and climate change and variability figure in these dynamics.

More recently, the Government of Ethiopia has been initiated and implemented different intervention policies to address these multifaceted problems (UNDP, 2014). Such intervention measures include application of massive soil and water conservation through watershed rehabilitation campaigns; promoting natural regeneration of vegetations through enclosure of degraded hillside; providing rural land registration and use right certification as a means of strengthening tenure security and providing natural resource conservation related capacity building trainings. Furthermore, through the SLM Program, funded by the World Bank, the government with its partners has made considerable efforts to show community-based grass roots approaches in pursuing participatory SLM planning at various sites.

Moreover, the Ethiopian Government has adopted a fifteen-year strategy to minimize the land degradation problems and promote climate-resilient green economy by 2025 (FDRE, 2012). The target of all these interventions is/was to trim down soil erosion challenges, enhance soil fertility status, improve micro-climate, boost up land productivity, prevent further land degradation and reverse degraded lands to mention but a few.

Despite these huge efforts, massive expenditures and significant achievements, the adoption rate of SLM practices is low and land degradation, biodiversity loss, poverty and food insecurity continue to persist as the major challenges that need a serious and prompt responses (Hurni et al., 2015). Moreover, debates are still ongoing over the idiom of community-based approaches in addressing these interlocking set of challenges and the space between the rhetoric in favor of integrated approaches (biophysical and socioeconomic dimensions) and reality of the success of the interventions to stop/ reverse the progress of land degradation and address local livelihoods.

1.2 Problem Statement

It is not exaggerated to say that agriculture sector is the main stay for the rural community and the backbone of the economy of Ethiopia (Tamene et al., 2011; FAO, 2011). This implies that the productive potential of agricultural lands determines the fate and prospects of both present and generations. Due to this fact, Agriculture has long been a priority area and a hub of national policy which was/is anticipated driving the overall economic development of the country. It is widely understood, however, that land degradation associated resource depletion is a major challenge particularly in agricultural landscapes. The upper catchment of the Beshillo Basin, where the study area lies, is one of the typical highland areas in North eastern highlands of Ethiopia where environmental degradation has been a challenge to the region. This severe environmental degradation has had a magnifying effect on the local livelihoods that requires urgent intervention measures. In the case study area, it could be recognized that historical unsustainable land use, high population pressure, uneven spatial and temporal distribution of rainfall, hilly and rugged terrain (which allows for easy soil run-off), low vegetation cover, small and highly fragmented holdings together with inadequate investment in SLM, progressive expansion of cultivation onto steeper slopes, lack of fallowing periods, limited or lack of access to credit and inputs, and use of crop residue and manure for fuel in preference to soil fertility management, intensify environmental degradation**.** These issues are all closely interrelated and interwoven in a complex and mutually re-enforcing cycle of environmental trap, which has led to enduring food deficient, persistent poverty and associated household food insecurity. This is evident from the large number of productive safety net program beneficiaries and yearly food aid dependent population in the study area. Beside the local socio-economic and bio-physical challenges mentioned above, the impact of global climate change and sporadic drought exert extra strain affecting the livelihood pattern and strategies of the community.

In light of such embedded problems, the government in collaboration with a variety of international donor agencies and NGOs has made strenuous efforts to address these multifaceted challenges (UNDP, 2014). In recent past, SLM has been considered as the best way to combat land degradation problems and even reverse degraded lands and to make a living in an economically, socially and ecologically sustainable manner (MOFED, 2010). These interventions include application of massive SWC structures; promoting rehabilitation of vegetations cover through exclusion of degraded hillside; provision of rural land registration and use right certification as a means of strengthening tenure security have been mentioned.

Although there are encouraging results, the extent to which land degradation has declined or unabated and to what extent the efforts move forward in improving local level livelihood concern is not well known, as population pressure and climate change and variability figure in these dynamics. Moreover, despite widespread recognition of, and all these intense past efforts, the views of local communities associated with the implementation approaches, community's preference, satisfaction levels and barriers facing the sustainability of proposed measures have not been systematically assessed.

With this broader context in mind, this study was aspired to assess the context and realities whether the interventions control land degradation and rehabilitate degraded lands or otherwise, through interdisciplinary methodological approaches and evidence-based analysis of remote sensing and on-site data along with local communities' historical environmental change perceptions. It also examines the most commonly used land management technologies, implementation approaches, factors influencing implementation efforts, outcomes on the physical environment and the livelihoods of local communities and the opportunities for and barriers to sustainability prospects in the watershed.

1.3 Objectives of the Study

The overall objective of this study was to assess the current status and future prospects of sustainable land management and evaluates its implication on the environmental integrities and the local livelihoods at watershed levels.

In particular, the study tries to addresses the following specific objectives:

1. To evaluate the dynamics of LULC, investigate its drivers and analyze implications in study watershed
2. To assess the magnitude of soil loss rate by using RUSLE model and identify priority areas for conservation in the watershed
3. To Assess effects of LULC types and agro-ecologies on soil physiochemical properties in the study area
4. To assess existing sustainable land management practices vis-à-vis policy framework and Sustainable land/watershed management principles
5. To assess the challenges and prospects of SLM practices from farmers' perspective in the watershed

1.4 Research Questions

Based on the specific objectives outlined above, the following sets of research questions have been stated as guide:

1. What are the extent and degree of the spatio-temporal dynamics of land use/ covers? What are the major driving forces? What are the possible implications of these changes?
2. What are the existing magnitudes of soil erosion rate in the watershed? Do farmers perceive soil erosion as a problem in the watershed?
3. To what extent do specific land use/cover types affect soil physico-chemical properties across agro-ecologies in the watershed?
4. What is the current status and future prospects for sustainable land management initiatives and actual practices in the Watershed?

   What the current patterns

   4.1. Which sustainable land management technologies have been or are being applied within the specific land use systems/agro ecologies in the study area?

   4.2. To what extent do sustainable land management approaches involve local communities and satisfy the requirements set forth in the policy frameworks and implementation guidelines?

4.3. To what extent do implemented technologies improve environmental attributes and local livelihoods in the context of Gedalas watershed?

5. What factors constrain the success and sustainability prospects of SLM practices in Gedalas watershed?

1.5 Motivation and rational for the selection of the watershed

The Beshillo catchment (most of its catchment lies in South Wollo) is highly fragile, dissected and physically remote area. In terms of socio-economic development indicators, it is comparatively among low developed parts of the county. Despite a number of studies exist on SWC issues in Ethiopia, to the best of my knowledge; such studies have been rare in the Beshillo catchment in general and Gedalas watershed (case study site for this research) in particular. Some of the justifications for the selection of Gedalas watershed for this study include:

1. The watershed is typical of the central highlands of Wollo, Ethiopia, where farming activities has a long history and residents would continue farming there. Moreover, the watershed is assumed to represent most of the areas of the Beshillo catchments in terms of its biophysical (agro-ecology, terrain configuration, soil characteristics, climatic conditions, and vegetations), socioeconomic background of the farming communities, and the history of land management interventions. Hence, the findings of this study reflect land degradation-rehabilitation dynamics of most of these catchments.
2. This area is one of the parts of the country which has been historically affected by the interwoven, multifaceted and mutually reinforcing soil erosion, food insecurity and drought induced famine problems more than elsewhere in the country. Soil erosion is a serious problem as manifested by numerous rills and gullies. Natural vegetations have been declining and biodiversity of the area have been falling down. The productivity of the land becomes insufficient to sustain the rising population of the watershed.
3. Furthermore, personal experiences of the author about the hardship of life, the poor productivity of farmlands, the prevalence of recurrent drought and the struggle of the local farmers to cope with these interlocking challenges in the watershed activated me to develop an interest for this study.
4. Above all, it is unnoticed area in terms of research despite it represents the more severely degraded region of the Beshillo catchment probably due to ruggedness of the topography and associated inaccessibility and lack of good public transport of to conduct the research in the study area.

1.6 Significance of the Study

In a wider sense, this study involves spatio-temporal dynamics and population-environment interactions in the study of prospects of sustainable land management practices through watershed approach. Hence, it will complement and contribute to the expansion of geographic knowledge on the extent of environmental management efforts that have implications across socio-economic, biophysical, and geographical settings.

More explicitly, the study is expected to have the following significances:

1. There are a number of literatures related to land degradation and restoration issues in Ethiopia. However, many of these works may not be significanct with regard to the specific situation with different socio-economic and environmental settings like Beshillo catchment. This study is one of the first attempts in assessing existing land management strategies and sustainability prospects at the watershed level in this little known Beshillo catchment. Hence, Gedalas watershed, as part of the Beshillo catchment, elucidate the state of the physical environment and on the knowledge base of all stakeholders with regard to land degradation status, sustainable land management approaches and technologies vis-à-vis SLM principles, government's policies and strategies. The study also complements the extensive body of research already existent in the country, through providing baseline information.
2. The study expects to contribute to the policy discussion on SLM intervention. By clarifying the complexity of the underlying problem, the study is anticipated to highlight the sucess of SWC measures in particular and sustainable land management in general in northeastern highlands of Ethiopia. It also contributes to fill knowledge gap as it provides insight for attitudes of the main stakeholders (i.e., basically the local people) on both land degradation and rehabilitation dynamics since they are the major actors in influencing the failure or success of sustainable land management application.
3. This research has also international dimensions since it is linked to universal sustainable development goals (Goal 15 and Target 15.3), of the United Nations Convention to Combat Desertification (UNCCD) which urges countries to restore, care for and promote sustainable use of resources (UNCCD, 2015). Another area of international significance is the fact that spatially the study area is located in the Eastern Blue Nile Basin and would contribute pragmatic evidences for basin wide resource management interventions.
4. The study is in line with the current Ethiopian Government's campaign for sustainable land management and climate resilience green economy programs in the country as enshrined in the two-phase five-year (i.e, 2010–2015, 2015–2020) Growth and Transformation Plan (GTP) documents (FDRE, 2011/15). GTP II, in its strategy, clearly stipulates the need to improve natural resource conservation and utilization in three areas of activities: rural land administration, watershed management and expansion of small-scale irrigation (FDRE, 2015). Furthermore, Ethiopia has visions and began to develop and fully utilize its water resources to trim down the prevalence of poverty and insecurity of energy in the country. It was against this hope that the 'The Grand Renaissance Dam' is under construction over the Abay (Blue Nile) basin, where the study

area is one of its sub catchments. Hence, the information gained through this research provides insights into how sustainable land management intervention is being translated into practice which has direct implication on flood and sediment load risks of the dam. Hence, this study is timely and demand-driven.

5. Finally, since it depends on the new paradigms of integrated (social and natural science) research approaches, this research believed to have methodological contributions. In academic areas, the output serves as an additional resource for teaching and/or reference material in higher institutions or elsewhere.

1.7 Scope and Limitation of the Study

1.7.1 Scope

This research seeks to understand, current state of soil erosion and selected soil physico-chemical properties as reflected by state and trends of LULC dynamics and agroecologies by taking Gedalas watershed as a case study site. It also examines the existing land management practices, implementation approaches, outcomes and sustainability prospects vis-à-vis government policies and strategies.

1.7.2 Limitation of the Study

It is obvious that any research output would not be free from certain limitations. Some of the problems the researcher faced during the study were time and financial constraints; lack of historical population data for each sub watersheds, limited access to internet; challenges of access to some of the sample sites due to distance, uncomfortable terrain and the mountainous nature of the research made travel difficult during data collection. Some of the respondents also faced the challenge of vividly recalling their past land use activities and environmental conditions despite an attempt was made to associate the questions with event calendars. On top of these, though most of the farmers and government officials were transparent, some of the respondents were slow and reluctant to respond on some questions by relating it to political issues. Because of a lack of historical and high-resolution remote sensing data LULC analysis mainly focuses on the last four decades and based on medium spatial resolution images. In addition, LULC transition analysis was limited to inter LULC spatial occupancy changes. More systematic transformations within a land use/cover category (e.g. change in tree species) were not addressed in this study though they have considerable implications on the production potential and integrity of watershed ecosystem functions. Besides, the findings of the soil loss estimation were not validated on plot-based actual measurements taking into account each LULC categories and management interventions across agroecologies.

Despite all these challenges, every possible effort was made to maintain the quality of the research output and minimize the impacts of the challenges encountered. For example, to minimize farmers' reluctance of sharing information, diplomatic probing and triangulation of information (asking the same question in different ways) was employed and assured them of confidentiality of their response. To fill in the gaps related to the relative scarcity of official documents, interviews were held with selected community members and concerned government agents in order to complement the analysis with narrative data. To validate soil erosion estimates, inference of data from adjacent sites where actual measurements available were made. However, if not for these challenges, the quality of this research output would have been much better.

1.8 Thesis Organization

This thesis is organized into nine chapters. The first chapter sheds some light on background information, the problem statement, the core objectives of the study and the fundamental questions the study seeks to explore. Furthermore, this chapter set out the significance of the study and justification for the selection of study sites. It also explains the research assumption, scope and limitation of the study.

Chapter two reviews existing empirical and theoretical relevant literature on the discourses of human-environment interactions and dynamics that have emerged over time. Moreover, the conceptual framework of the study was presented here.

The third chapter deals with the methodology of the study. It also provides a glimpse of the biophysical and socioeconomic settings of the study site, the research philosophical foundations and the research process including preparations for the fieldwork, the specific research methods that were utilized to address each research objectives. It also explains the types of data used and tools employed to collect these data, methods of data analysis and the presentation of results are discussed. Finally, Ethical considerations were highlighted.

Chapter four to eight presents the findings of the study, in which chapter four corresponds to objective one, chapters five, six, seven and eight correspond to objective two, three, four and five respectively. Chapter four explores the spatial and temporal dynamics of LULC of the study area. Chapter five provides assessment of Soil erosion risks within the existing watershed management scenarios. Chapter six describes Soil fertility status under selected land use/cover types and agro-ecologies of the watershed. In chapter seven special emphases was given to the local actions on SLM practices and approaches vis-à-vis Policy instruments and sustainable land management principles. Under this chapter, the efficacy of land management interventions on the environmental dimensions and contemporary livelihoods were analyzed from farmers' perspective. Chapter eight presents sustainability challenges and opportunities for promotion of SLM practices. Each of these chapters presents the findings of the research and data analysis under the sub topics of various themes (based on research questions). The last chapter draws the main conclusions from the previous analysis and proposes considerations for the effective land management strategies.

CHAPTER TWO

2 THEORETICAL PERSPECTIVES AND ANALYTICAL FRAMEWORKS

2.1 Introduction

This chapter provides a review of literatures flanking on land degradation-conservation discourses, political ecology of human-environmnet interactions, historical development and paradigm shift in SLM practices and its determinants and other related issues in a broad perspective. Based on theoretical and empirical reviews, conceptual frameworks were constructed for the investigation of the topic of interest in the study.

2.2. Theoretical Perspectives

2.2.1 Changing Paradigms in Land Degradation-Conservation Discourse

Over the years, there are divergent opinions and debates at global level on the existence, causes, level and scale of land degradation in the literature. As far as the process, severity and impacts of land degradation is concerned, there are two major schools of thoughts. The first school of thought reflects that land degradation is a serious global environmental challenge to human beings, because it threatens productive potential of land resources and quality of the environmental at large (Dregne and Chou, 1992). The second school argues that land degradation is not a serious challenge as it is exaggerated (Crosson, 1997; Pimentel, 1993).

In an effort to address the old aged problems of land degradation, three basic paradigm shifts explaining land degradation and conservation approach has been evolved in the literature over time (Biot et al., 1995; Blaike et al., 1997; Brown, 2002). These are the classic, the populist, and the neo-liberal approaches. Despite all these three paradigms describe human-natural resources nexus differently; they were not strictly sequential and exclusive in their historical development.

The first of these is the classic paradigm, which was predominant between 1950 and 1975, expounds population increase in a Malthusian way as threats to natural resources and claims that if the demands of a growing human population overtake the capacity of an environmental system to support it, an ecological crisis will erupt. This implies that this school of thought associated land degradation with population increase and poverty. They clarified that raise in population number causes stress on land resources, forcing farmers to plow marginal lands which are not conducive for cultivation (Blanco and Lal, 2010). Therefore, the need for population control and state instigated and exclusionary approaches to natural resources conservation and management is compulsory (Stephenson *et al*., 2010).

This school of taught further undermines farmer's capacity to innovate and develop resource management strategies appropriate to their existing conditions and assumed that indigenous knowledge is part of the problem, leading to backward production techniques and environmental degradation. This group of scholars believed that since local knowledge is defective, irrational, traditional and nonscientific for managing natural resources sustainably, it should be replaced by the adoption of technocratic solutions that are expert led knowledge and officially sponsored innovations (Blanco and Lal, 2010). Put in other words, this group favors 'top-down' and coercive transfer of technology (Blaikie, 2000). They believed that proper land management is realized through the government's designed technologies and approaches that need people to implement it.

The second paradigm referred to as populist (people centered or bottom up approach), which appeared in the late 1980s, claims that land degradation is the outcome of wrong land use policies and actions of the state (Ananda and Hearth, 2003). This group claims that despite poverty and high population growth, local communities can not deliberately devastate their environment upon which their livelihood depends (Scoones, 2010). In this line, Tiffen *et al.* (1994) have vividly pointed out that the case of Machakos District of Kenya as "albeit *high levels of poverty and rapid growth of population, their environment has been successfully conserved*". This school of thought further advocates decentralized and community-based approaches as a key strategy to natural resources development and management. This approach argues that protection of land has to be part and parcel of local people's production systems. This view stresses the positive role of local experience and underscores bottom up stakeholder participatory interventions in land management practices (Reij, 1991). It is based on the argument that since local knowledge is a valuable and underutilized resource it has to be integrated in resources conservation technology innovations and adaptation process (Pretty and Shah, 1997). This school of thought advocates that technologies will only be accepted if they are developed by and with the local communities, and address the needs and local contexts (Mazzucato and Nineijer, 2000).

The third paradigm is the neo-liberal approach, which takes a middle position, integrates both classic and populist views and advocates the need to adopted or adapted available technologies to control land degradation and understand the existing policies, regulations, approaches, incentives and institutional set ups that prevents local people from adopting and adapting the recommended land management technologies at the farm level (Biot et al.1995; Adger et al, 2001; Suich, 2013). This study adapted the neo-liberal approach as its theoretical backdrop and favors the view that although there are dozens of technologies available for SLM practices the adoption and sustainability these technologies are much below expectations due to various biophysical, socioeconomic and institutional pitfalls. Hence, the problem of land degradation remains unabated in Ethiopian highlands in general and the Beshillo catchement in particular.

2.2.2 Political Ecology of Human-Environment Interactions

The term political ecology was first used in the literature in late 1960s and 1970s (Wolf, 1972). Political ecology is a multidisciplinary field that has emerged from the growing concern of the influence man on the biophysical environment and ecosystems. It becomes popular in social-ecological research as an approach of analyzing human-environment interactions in their political and economic context (Forsyth, 2004; Bixler 2013). Although political ecology has been applied to a variety of theoretical and methodological approaches, relationships between humans and the environment are its central concerns. Many authors argued that political ecology has a strong base to examine the human-environment interactions (Stringer, 2004; Jones, 2008; Anderson et al, 2011). According to Blaikie and Brookfield (1987) political ecology integrates ecological concern to that of political economy. Bixler (2013) similarly argue that Political ecology seeks to address the reprocal influence of human beings and the environment over time. Bryant (1992) contends that political ecology is an inquiry into the interactions of various socio-political forces, and their implications on the local environments.

Hence, political ecology is a powerful framework for human environment relations, which are a key theme of geography and this study (Campbell and Olson, 1991; Olson et al., 2004). For this research contemporary political ecology theoretical framework is used to elucidate changes in land use and land management aspects. This approach emphasizes on impact of policy reforms, strategies and approaches,; enforcement of laws; enhancement mechanisms of the institutional, the link between watershed level interventions and relevant national and regional policies; intersectoral cooperation; integration of scientific and local knowledge; capacity building and awareness raising issues considered for implementation sustainable land management activities in the study area.

2.2.3 Land, Land Use and Land Cover: Definitions and Narratives

Land is one of the most fundamental resources human beings have (FAO, 2007). Land resources are an essential natural asset and an integral component of the watershed which provides social, economic and ecological functions to sustain rural livelihood of the inhabitants. However, land is becoming a limited resource subject to competing demands and its various functions and services are seriously compromise by the problem of land degradation (Gessesse *et al,* 2015). Sustainable management of this resource is, therefore, an urgent issue nowadays worldwide (Lakew,2018). Consequently, monitoring status of the land is required to reach the intended targets of sustainability and ecological stability. In this regard, the LULC and its implication have generally been considered as major driver of local and global environmental change and become important signals of regional environmental status and parameter in the evaluation processes (Turner *et al.,* 2007).

Land use/cover data provides crucial baseline information for land degradation assessments, evaluation and monitoring. Changes in land use/cover may serve to indicate where degradation is likely to occur and suggests priority areas for SLM practices (Moges et al., 2018; Hu et al., 2019).

2.2.3.1 LULC Change, It's Driving Forces and Implications

LULCare closely linked but distinct characteristics of the Earth's surface (Jansen and Di Gregorio, 2002; Ellis and Pontius, 2006; Comber, 2008). Though often conflated in classification schemes, they are all different datasets unfolding the environment in relation to both natural processes and human- environment interactions. FAO (2007) defined land use as "*human modification of a natural environment or wilderness into a new environment such as agricultural fields, pasture and settlement*". Land use implies interference by humans with the intention to utilize land resources for economic and social purpose. Land use denotes the human use of the land for different activities while land cover refers to the biophysical attributes, which are of either natural and/or human origin, covering of the earth's surface (Jansen and Di Gregorio, 2002; Jansen, 2010). Turner *et al. (*1995) elucidate land cover as the observed (bio) physical cover on the earth's surface and immediate subsurface. Land cover is generally accepted as one of the most representative indicators of environmental quality.

LULC change is the quantitative change in LULC types (Bey et al., 2016). Changes can be conversion or modification (Turner *et al.,* 1995; Lambin *et al,* 2003; Lambin and Geist, 2006). LULC conversion represents alteration of one use/cover category to another new land use/cover types while LULC modification refers to amendment of structure or function of LULC types without a complete change into another (Lambin *et al.,* 2003). In this study, the argument is that Spatio-temporal pattern of LULC change is the response of evolving economic, social, and biophysical conditions and is the proxy indicator of land degradation-restoration dynamics of the study area.

As noted in the preceding section, spatial and temporal pattern of LULC of a given sites are an outcome of biophysical and anthropogenic driving factors (Lambin *et al.,* 2003; Briassoulis, 2008; Su *et al.,* 2011). Hence, the status and dynamics of LULC is one of the main proxy indicators of the level of human-environment interactions (Anil *et al.,* 2011). Human beings influence land resources and have modified natural environments to satisfy their needs since their existence. Many revealed that although the evidences for LULC dates back many thousand years, the recent pressure of human on land and its scarce resources is more intense than in any comparable period of time (Petit and Lambin, 2002; MEA, 2005; Ellis and Pontius, 2006). This unprecedented human-environment interaction has been demonstrated by LULC changes and occurs at both temporally and spatially at various scales.

Some studies also categorized and documented LULC change driving forces into proximate and underlying categories (Lambin *et al.,* 2003). The proximate forces comprise human intended actions of land use that directly affect land cover (Turner et al., 1995) while the underlying forces elucidate the fundamental forces and broader socioeconomic and political contexts that act behind these intended and local actions (Lambin and Geist, 2006). Su et al. (2011) argue that proximate driving forces are relatively static and easy to quantify while anthropogenic factors, due to its diverse nature, are difficult to quantify despite it reflects landscape change accurately. Although LULC change is global phenomenon, its nature and magnitude varies spatially and its consequence is strong particularly in fragile ecosystem and mountainous areas.

Despite LULC change have social and economic benefits; this dynamic and complex process usually has unintentional interlocked multidimensional implications upon essential functions of the Earth's ecosystem services at all spatial levels (Lambin *et al.,* 2001; Turner *et al.*, 2007). For instance, changes in LULC have been shown to have negative impacts on biodiversity (Ellis and Pontius 2006), biogeochemical cycling and soil erosion (Douglas, 1999), livestock, stream water quality and contribute to climate variability and change of any scale (UNEP, 2014) which all have implications on the provisioning capacities of the watersheds. Undesirable land cover and ecologically incompatible land use are major contributory factors for accelerated soil erosion and associated land degradations (Pimentel, 1993; Mwehia, 2015).

Periodic LULC change monitoring is an essential requirement for the evaluation of ecosystem health and investigate factors responsible for triggering the dynamic processes and resulting consequences (Lambin and Geist, 2006; Fichera, 2012). Moreover, information on LULC dynamics assists in monitoring environmental changes and developing effective land management and planning strategies at both national and local levels.

2.2.4 Historical Background and Concepts of Sustainable Land Management

Initially the concept of sustainability as a new development paradigm came into view from the 1972 United Nations (UN) Conference on the Human Environment held in Stockholm, Sweden, in which participants agreed up on the widespread evidence of environmental degradation. In 1987, the World Commission on Environment and Development (commonly known as "*the Brundtland Report*") defined sustainable development as "... *development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" and called for progress in achieving sustainable development (WCED, 1987:49). This implies economic advancement and progress while protecting the long-term value of the environment.

The concept of SLM was an outcome of the1991 workshop organized by the International Board for Soil Research and Development held in Chiang Rai, Thailand (Dumanski, 1997). The concept was further gained recognition as one of the global issue in sustainable development discourses (Smyth and Dumanski, 1993). However, the term sustainable land management was explicitly used for the first time in an FAO document entitled "FESLM: An international framework for sustainable land management" (Smyth and Dumanski, 1993). Since then it emerged as a concern of priority on the global agenda and various definitions and descriptions have been proposed by different scholars and organizations to further elaborate the concept (Hurni, 2000). The growing awareness of land degradation and associated problems of food security, climate change, and desertification as well as the increasing news coverage of land related issues constitute to emergence of the concept of SLM (Breu et al, 2011).

Various definitions have been forwarded about SLM on published literatures. Smyth and Dumanski (1993:12) in "A framework for Sustainable Land Management" defined the SLM as the" integration of technologies, policies and activities aimed at combining socioeconomic principles with ecological concerns so as to concurrently sustain production/ services, reduce the level of production risk, protect the potential of natural resources bases and ecological balance, contribute to sufficient income and promote social acceptability.

Hurni (1996:27) defined SLM as "*a system of technologies and/or planning that aims at integrating ecological with socio-economic and political principles in the management of land for agricultural and other purposes to achieve intra- and intergenerational equity*". This implies that achievement of SLM practices should be viewed from ecological, socio-economic, institutional, and political dimensions.

WOCAT (2007:10) defines SLM as "*the use of land resources, including soils, water, vegetations, and animals, for the production of goods and services to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and ensuring their environmental functions*".

Mitiku *et al.* (2006) pointed out that sustainable land management has emerged as a new strategy and concept to combat both poverty and environmental degradation due to mounting population pressure on scarce land resources and subsequent growing demand for agricultural use. World Bank (2006) states that SLM not only improve the productive potential of land and sustain the ecological integrity of the watershed but also stop and reverse land degradation. Liniger et al., (2011) also defined SLM as a knowledge-based implementation of land use practices and integrated management of environments to meet rising demands on land resources without compromising ecosystem services and local livelihoods. This implies that SLM is the adoption of land use practices that harmonizes the complementary but often conflicting objectives of increasing economic and social benefits from the land, while maintaining the ecological support functions of land resources. It seeks to put forward achievement of these conflicting objectives simultaneously in a win-win approach.

Despite all the foregoing definitions are offered in different ways, the messages are equivalent and the essence of all these blend of definitions indicate that SLM is an appropriate land use practices that seeks to harmonize the conflicting objectives of maintaining or enhancing ecological integrity while at the same time promoting sustainable rural livelihoods in integrated manner (Noe, 2014). SLM is a cornerstone to counter land degradation, promote biodiversity, mitigate climate change, support ecosystems functions, enhance production and ensure food security (Critchley and Radstake, 2017).

In essence, the concept of SLM embraces the integration of biophysical, socioeconomic and environmental dimensions in holistic approach (Woodfine, 2009). This implies that the potential success of SLM programs should be evaluated in terms of economic, social (include policy, institutional and cultural aspects) and maintenance of natural environmental components (such as biodiversity, water availability and quality, soil fertility etc) over time (Smyth and Dumanski, 1993; Haile et al., 2006). If any one of these dimensions is not properly considered, the use of a land resource might not be long-lasting sustainable.

In the context of this study, Sustainable Land Management could be defined as management and use of land and land resources for various purposes to meet community's livelihoods needs while concurrently assuring the long-term socio economics and ecological functions of the land. It includes actions to stop or minimize land degradation, combined with measures to reverse degraded lands through systematic use of appropriate technologies such as application of various SWC measures (Structural and/or biological, Indigenous and/or introduced), enclosures, integrated soil fertility management practices, harvesting and management rain water, proper management of grazing lands, in an integrated manner thereby to increase crop and fodder production, reduce surface soil erosion and runoff, increase vegetation cover by the use of plant species adapted to local conditions, improve biodiversity conservation, enhance soil fertility status, improve availability of water resources and water-use efficiency and adapt climate change impacts with active participation of communities and abetted by appropriate policy instruments and intervention guidelines.

As suggested by Liniger et al. (2011), adoption of SLM technologies, along with an enabling institutions, help minimize land degradation, promote rehabilitation of degraded landscapes; improve status of soil fertility and resistance to erosion; improve storage potential, productivity and efficient utilization of water resources, enhance biodiversity; improve land productivity, maximize livelihood options enhance resilience to natural disasters, among others.

2.2.5 Sustainable Land Management Principles, Technologies and Approaches

SLM is the way out from the interwoven and mutually reinforcing problems of land degradation, climate change and variability impacts, vulnerability, and perpetual poverty at the household level of rural areas.

2.2.5.1 SLM Principles

Sharma (1997) suggested the following lists of guiding principles for successful SLM/watershed planning process, such as development and management systems according to needs and capacities of people; technical appropriateness, feasibility and cost effectiveness of planed interventions; participatory planning and implementation of approaches; promotion of community management and maintenance systems;

adopt holistic planning and an integrated approach; ensure gender equality in planning and decision making and make monitoring and evaluation an integrative part of the process.

2.2.5.1.1 Land management Sustainability components

FAO (2006) indicates some of land management sustainability indicators including e**cological Sustainability (**SLM interventions should be ecologically protective and should maintain a stable resource base of all land resources); t**echnological sustainability** (since every geographic area has its own unique characteristics which are mediated by the local community in intricated and often unique manner, SLM technologies should be context specific. In addition, approaches to SLM interventions should be process-oriented and flexible to the changing circumstances); s**ocial and cultural Sustainability (**SLM planning and actual implementation should be based on consideration of indigenous knowledge, experiences and cultural norms. It should ensure fairness in cost and benefit sharing mechanism among the participating communities irrespective of gender, wealth status, educational background and other parameters); e**conomic sustainability:** SLM interventions should enable land to produce on a continuing basis. It should also address short term eco (nomic needs without compromising long-term vision) and i**nstitutional Sustainability (**the sustainability of government institutions, advisory support service providers, community-based organisations and their effectiveness in achieving SLM goals. This includes capacity to plan, coordinate human activities, implement and monitor SLM activities, to provide relevant and timely information in sustainable manner). Moreover, accountability, transparency, Property rights and Collective action and empowerment of women's group are important indicators of institutional sustainability.

2.2.5.2 SLM Technologies

WOCAT (2007:11) describe SLM Technologies as "a *physical practice on the land that controls land degradation, and enhances productivity and/ or other ecosystem services. A Technology consists of one or several measures, such as agronomic, vegetative, structural, and management measures*". To be successfully adopted by the land users, SLM technologies should ideally be simple to understand and implement by the land users; low cost in terms of financial reach, labor requirement and land consumption; conservation effective and productive; sustainable; be non susceptible to risk and flexible.

2.2.5.3 SLM Approaches

As documented by Hurni (2000), approach is defined as "*the ways and means" (e.g.* legal framework and policies, technical assistance and material support, participation of stakeholders etc) used to introduce, implement, sustainably apply proposed SLM technologies/ programs in the field. In confirming this, Liniger et al., (2011) stated that SLM technologies need approaches that enable and empower people to accept, put into practice, adopt, and spread best practices.

For the last few decades, different approaches have been employed to revere environmental degradation trends and to boost production in many countries. To decrease the current pressure on land resources and enhance wide adoption of SLM practice, contemporary literatures (E.g. Tukahirwa et al., 2013) proposed the following SLM approaches:

1. Land User Driven and Participatory Approaches

Since environmental problems are complex and multifaceted in nature, it entails flexible and apparent decision-making following multidisciplinary approaches (Reed, 2008). To achieve better outcomes in SLM practice, involvement and representation of communities' voices and keen interest should be viewed as relevant components in all phases SLM decisions. Stakeholder participation is the process of genuine involvement of all concerned and relevant parties throughout all phases of SLM decision-making, where their knowledge, needs, interests and concerns are actively sought, and have some degree of influence on decision-making processes. The participation assumption as a means to consider local outlook and indigenous knowledge development programs has gained a lot of popularity during the last few decades (Scoones and Thompson, 1994).

Botes and Van Rensburg (2000), states the reason for the implementation of SLM practices through participatory approaches as follows: First, SLM can only be sustainable if planning and implementation practices are made with participation of the people. Second, participatory approaches create opportunities for two-way communication, in which farmers and government agents express their views, listen to each other, understand and compromise, clarify the values and trade-offs, based on mutual respect. Third, participation shift power dynamics in favor of marginalized groups and individuals. Fourth, participation ensures sustainability by developing sense of ownership among local communities.

Generally, the use of participatory approaches in SLM not only facilitate knowledge-exchange between community participants and convening government agencies but also help understanding of local issues, problems and conditions that could lead to practical, relevant, achievable and acceptable solutions to land related problems which in turn ensures public trust, acceptability and sustainability of SLM practices by the local community.

Botes and Van Rensburg (2000) have also indicated some Challenges for effective community participation, namely; prescriptive approach of government and professionals; exaggerated successes reports; discrimination in participation; contradictory interest among community members; dominating role of local elites; eagerness for short term benefit; and lack interest to participate and so on.

Similarly, Cook and Kothari (2001) and Reed (2008) posit a number of criticisms on the issue of local community participation. Some of these criticisms are: the objectives of participation has lacked intellectual rigor and not sufficiently and critically appraised; participation are superficial, tokenistic and exploitive;

dangers inherent in privileging local knowledge over ‘legitimate’ expert knowledge; local communities may be portrayed as benign and homogeneous, to mention but a few.

Despite these criticisms, there are a number of experiences and commentary research report that identifies a number of alternatives for addressing these blames. For example, Prior (2010) argued that the critics indicated in the forgoing section can be solved through identification of relevant area of communities’ participation in planning and decision making course of action; considering the divers views of the community instead of assuming them as homogeneous and incorporation of the views of disadvantaged groups instead of depending on the views of the more powerful ones. Moreover, to build trust in the participation process and avoiding unrealistic expectations of the community, providing timely feedback to participants as to how, and why, their views have or have not been implemented (Sseguya et al, 2009).

2. Multilevel and multi stakeholder approach

Multi-level stakeholder approaches are forefront to promote SLM and to address persistent land degradation trends (Lange et al 2015). According to Hurni (1998, 2000), multi-level indicates all levels, ranging from local to international delegations who directly or indirectly involved in SLM programs while Stakeholders are local communities or institutions who shares common interest for the implementation of SLM activities such as farmers, administrators, researchers, development agents, and others. Muchena and Bliek (1997) categorized these stakeholders in to insiders (the resource users) who are responsible to use and manage land resources in the area and outsiders (*e.g.,* governmental and non-governmental organizations) whose task is not only defend the community needs but also advise, facilitate and assist the resource users.

‘Multi -level-stakeholder’ approach advocates that since land degradation is a multifaceted problem, ‘multi-stakeholder’ and ‘multi-dimensional’ approach are essential to find realistic, socially acceptable, ecologically sound and economically viable solutions at the local level (Hurni, 1998). Engagement and integration of stakeholder knowledge is an essential component of the SLM activities in that it helps to ensure that all views are considered when planning SLM options (Lange et al, 2015).

For this end, there should be active involvement of all relevant stakeholders such as concerned government agents, local communities and others working in the promotion of SLM practices and approaches there by to generate wide range of impacts which is difficult to achieve at individual level (Zeleke et al, 2006; Schwilch et al, 2012). Further, the approach recognizes the need for the integration of ecological, social, cultural, political and economical dimensions of SLM and coordination of all stakeholders from local to international levels.

3. Integrated Watershed Management Approach

Watershed is topographically delineated ecological unit of land which contributes runoff to a common point along a stream channel. The watershed is an area of land, a bounded hydrologic system, within which all natural resources (soil, water and vegetations), human population, farming system, livestock, and the interaction among these components are inextricably linked by their common water courses and which is influenced by unique biophysical and socio-economic attributes (Knney, 1999). Watershed is a hydrologic units and socio-political-ecological entity of natural resources planning and management which plays critical roles to support the livelihood of rural community (Brooks et al., 2012; Worku and Tripathi, 2015). In Ethiopian context, Desta et al (2005) defines the watershed as an area of land which constitutes all the biophysical (water, soil, and vegetative) components and socioeconomic features including local communities, their economic activities, social set up and their interactions with land resources.

From management planning point of view, Geyik, (1986) defines watershed management as "*the process of formulating and carrying out a course of action involving manipulation of land and other resources on a watershed to protect and conserve the environment and provide resources that are desired by society to attain their livelihood security*". Brooks et al. (2012: IV), define (integrated) watershed management as:

> *The process of guiding and organizing land and other resources use in a watershed to provide desired goods and services without adversely affecting land resources. It integrates various aspects of hydrology, ecology, soils, physical climatology and other sciences to provide guidelines for choosing acceptable management alternatives within the socio-economic context taking into consideration the interactions and implications among land resources and the linkages between uplands and downstream areas.*

The concept of integrated watersheds management, which emerged in the 1980s, is now largely accepted as a holistic approach for environmental planning, development, management and judicious use of natural resources, with active participation all stakeholders within the watershed (Sharma, 1997; German et al, 2007; UNDP, 2013).

Integrated watershed Management is broad based management approach to improve local livelihoods, agro ecosystem resilience, avert degradation, and sustain agricultural productivity and environmental services within a hydrological defined geographic area (Reddy, 2005; Kerr et al. 2007). It recognizes the inter-linkages between economic, social, and environmental components and geared towards the need for integration of these issues with guiding principles of equity, sustainability and stakeholder participation to understand their interests and priorities, appraise opportunities, and examine the outcomes (FAO, 2006; German et al, 2007; Shiferaw et al., 2009).

Integration involves managing diverse components, of the watershed, including vegetation, soil, water resources, livestock, crop production and other attributes through effective integration of practices/technologies to address community needs and priorities (e.g. conservation, food security, income generation) (German et al, 2007). Integration also implies blending knowledge from different disciplines, institutions and agencies (Liniger et al., 2011).

As per Community Based Participatory Watershed Development guideline of Ethiopia (Desta et al., 2005), the overall development and management practices of watersheds should be governed by the following principles: active participation of watershed communities (Participatory); Women participation and benefit sharing (Gender sensitive); building upon local communities experience, strength and works; should be realistic, integrated, productive and manageable that based upon locally available resources, capacity and other forms of institutional support; should be at an appropriate geographic scale and site selection should respect watershed logic (ridge to valley); be flexible and show continuous improvement; sharing of cost by stakeholders, building sense of ownership among the community members; should be sustainable and simultaneously increase food production, improve livelihoods, and protect biodiversity and ecosystem services.

Why SLM Through Participatory Integrated Watershed Approach?

As noted above, integrated watershed Management is a preventive, progressive, corrective and curative approach for the sustainable development and management of natural resources for the benefit of the community in a given watershed.

There are several reasons for using integrated watershed Management approach for SLM planning and management: First, watersheds are physically easy to define and replicate. Second, watersheds are based on natural hydrology and have relatively fixed boundaries which can be used as practical units for better understanding problems and conditions to develop comprehensive solutions in managing resources as part of a system. Third, watersheds are integrated land units that comprise socio-economic and biophysical attributes whose component parts are interdependent. This implies that watershed management is directly associated with biophysical environment and local livelihoods. Forth, watershed development incorporates all of the programs, resources and regulatory tools available to protect ecosystems and human wellbeing within the watershed. Watershed approach uses integrated and comprehensive strategies in which all components of the system (biophysical and socioeconomic) and their interactions in the management activities and in evaluating and assessing natural resources problems. Fifth, watershed approach emphasizes public participation in natural resources management planning and decision-making processes. Finally, watershed development approach believes in community needs govern development agenda and encourages planning with the involvement of all stockholders and recognition of their interests at the grassroots level (Desta et al., 2005).

4. Landscape approaches

Landscape approaches is one of the recently conceptualized sustainable land management approaches to address complex landscape scale natural resources challenges (Sayer et al., 2017). This approach is about balancing competing land use demands in a way that is best for human well-being and the environment. Landscape approach acknowledges the complex nature of human–environment linkages and the need to consider this interaction in land management systems. It has evolved to integrate and reconcile the different resource attributes in the landscape, and the system of production, as well as the various demands of resource users on the landscape (Sayer et al., 2017).

2.2.6 Paradigm shifts in sustainable watershed/ land management approaches

During the last few years, the activities of watershed/land management had sectoral and narrow approaches which were focused more on soil through building physical structures and degraded hillside closures to stop land degradation and to reverse degraded lands (Desta et al., 2005). Unlike many of the SWC intervention programs in the past, the new generation watershed/land management focuses on integrated management of natural resources with the active participation of land users for the well being of their lives (Desta et al., 2005). This implies that watershed/land management is people centered and principally focused on local communities' needs and sustainable livelihoods concerns rather than merely satisfying the requirements of donors and governments or non-government organizations. Some of the different aspects of watershed/land management of old and new generations are summarized in the table below.

Table 2. 1: Comparisons of Traditional and new generation Views in land management approaches

The Traditional Views	The new generation Views (Current scenario)
Emphasis on central level (top-down) planning approach with little input from community and considers indigenous knowledge and tradition as inferior and backward	Emphasis on Participatory, community-based approach focusing on gender and social equity consideration, integration of indigenous knowledge and tradition into new technologies to establish systems of "hybrid knowledge".
Focused on single purpose (Soil conservation)	Focused on sustainable land management (Social, economical and environmental)
Sustainable watershed/land management is achieved by the construction of sporadic physical structures or biological barriers, along with application of fertilizers	Sustainable watershed/land management is achieved through continuous follow up and application of appropriate conservation measures and management strategies over time practices.
Land users were considered as naturally conservative, irrational, ignorant and their practices and opinion was considered as part of the problem of land degradation and hence coercion was used to spread and promote acceptance of 'expert' recommended 'solutions'	Land users make rational decisions in response to constraints they face, and are essentially focused on land productivity. Since local people have intimate knowledge of their surroundings, they should be viewed as part of the way out to solve land degradation problem and thus promote community participation in all phases of interventions.

among the community	
Emphasis on the increase of production and conservation issues within watershed/land management programmes	Emphasis on livelihoods, poverty and sustainability issues within watershed/land management programme
Focus on large watershed, on-site and short-term effects.	Focus on Small watershed, sub watershed, upstream-downstream linkages and long-term impacts.

Source: Adopted from FAO, 2006 and other related literatures

2.3 Empirical Review

2.3.1 Land Degradation in the International Arena: An Overview

Within the 'FAO-LADA Approach, land degradation is defined as "…*a decline in ecosystem goods and services from the land which negatively affects the state and the management of the natural resources*" (Liniger et al., 2011:18). Land degradation is one of the fundamental issues on the global environment and development agenda. It is a global challenge of our time because of its grave implications on the environment; agro ecosystem service provision, livelihood options and food security of people worldwide (Lal et al, 2012; UNCCD, 2015; UNEP, 2014). As reflected in the definition of Blaikie (1989), land degradation is the gradual decrease in the actual or potential productivity of the land under a specified form of land use and management strategies.

FAO (2004) defines land degradation as a temporal or eternal decline in land's productive capacity through human activity and/ or natural processes. Similarly, UNCCD defines land degradation as any decline or loss in the resource base of the land due to human activities and natural processes, and often exacerbated by impacts of climate change and variability (UNCCD, 2015). All these definition suggest that land degradation is a complex processes manifested by decline in environmental quality and land productivity which is caused human activities and natural factors, including climate variation **(**Vogt *et al.*, 2011; Hurni et al, 2015). Put in other words, land degradation is not simply an ecological issue, but also economic and social problems involving various types of intricate interactions and links between processes, derived by causes and affected by various factors (Blaikie and Brookfield, 1987; Lal et al, 2012).

2.3.1.1 Driving Forces and Extents of Land Degradation

There are divergent views on the causes of land degradation. However, land degradation is a multifaceted and complex dynamic process involving two interlocking complex systems, namely, human (socioeconomic, cultural, institutional and political) factors and exacerbated by natural (Biophysical) processes (Blaikie and Brookfield, 1987). As noted in the preceding section, drivers of land degradation are grouped into two proximate and underlying causes. Proximate causes are those that have a direct effect on the terrestrial ecosystem. These include natural disasters and climate change, topography, unsuitable land uses and unsustainable land resources management, deforestation and LULC changes. While the underlying causes are those that fuel the proximate cause and include in secured land tenure, land fragmentation, poverty, population (though population pressure and poverty-land degradation nexus is still controversial issue), and livestock pressure and weak environmental policy and regulatory environment, lack of or insufficient information about appropriate land management technologies, lack or limited access to farm inputs and credits, unplanned land use change, are the most commonly cited factors of the worldwide land degradation and associated loss of biological diversity and ecosystem services (MEA, 2005; Lambin and Geist, 2006; Kiage, 2013; Belay *et al.,* 2014; UNCCD, 2015; Nkonya et al. 2016).

Although land degradation is a widespread global risk, there is a great disparity in the extent and depth of the problems. Two-fifth of the degraded lands of the world is found in areas where there is highest level of poverty (Bai et al, 2008). According to Bai et al. (2008), more than 30% of forest resources, 20% of cultivated lands and 10% of grasslands experiences degradation and these degrading areas are occupied by more than 3.2 billion people of the globe. Besides its physical consequences on ecosystems the impact of land degradation is felt in socio-economic dimensions, including persistent poverty, water scarcity, food insecurity etc. As the result of land degradation about 5–8 million ha of previously productive land vanished out of farming at the global level per year (FAO, 2006). The estimate report added that the loss of arable land is 30-35 times of the historical rate while productivity of world's agricultural land reduced by 40-75% due to land degradation (UNCCD, 2015). According to FAO Global Land Degradation report one-fourth of the world's terrestrial land surface was highly degraded or degrading, and a extra 8% was somewhat degraded or degrading (FAO, 2010b).

The future predictions pertaining to land degradation are also not good news. In this view, Lambin and Meyfroidt (2011) hypothesize that by 2030 there is a need of additional land worldwide which might be fulfilled mainly by a combination of expansion to the forested areas and/or the conversion of productive but vacant lands. Similarly, UNEP (2014) postulates that by 2030, over one fifth of terrestrial habitats in developing countries could be converted to cropland if the existing land management practices continues unchanged and this will aggravate the losses of vital ecosystem services and biodiversities.

2.3.1.2 Global Efforts to Combat Land Degradation

There is a growing conviction that countries' struggle for poverty eradication and sustainable development is unlikely successful without effectively addressing land degradation challenges (Bai et al, 2008; Breu et al, 2011). Countries research report indicates, however, that there is promising future to avert land degradation trends and reverse degraded lands with appropriate interventions and efforts. This is supported by evidence that 2.7% of world's land area have showed improvement during the previous three decades (Le *et al.,* 2016).

Despite there have been persistent efforts by the global community to combat land degradation since the United Nations Conference on Environment and Development(held in Rio de Janeiro in June 1992), the success is still smaller as compared to the extent of the problem (Le et al., 2014). Cognizant of the need for a more concerted management of land resources than ever before, heads of states and governments of world adopted the Rio+20 declaration, the Future We Want' at the UN General Assembly held in 2012 and stressed on the issue of land degradation as an urgent and a top priority. They agreed to strive for the realization of land-degradation neutral world in the context of sustainable development (UN, 2012). Furthermore, land degradation neutrality and the need for SLM were established as one of the targets in the sustainable development goals as adopted by the UN summit in New York (September, 2015). Accordingly, goal number 15 of the sustainable Development Goals were adopted by the United Nations to care for, restore and enhance sustainable use land resources, combat land degradation and reverse degraded lands (UNCCD, 2015; Willemen et al, 2018; Solomun et al, 2018). It was in this line that the Addis Accord promoted the need for mobilization of financial resources for the achievement of SLM, protecting our ecosystems for all by combating desertification and restoring degraded land (UNCCD, 2015).

2.3.2 Land Degradation in African Context

Land Degradation is one of the pressing ecological evils and livelihoods challenges in Africa, where the greater part of people directly depends on land for crop production (Waswa, 2012; UNEP, 2013). Reviews of global assessment on land degradation confirm that Africa is the most vulnerable continent in the world (Lal, 1994; Stringer & Dougill, 2013; Reed and Stringer, 2016). The UNCCD estimates that Africa constitutes the lion's share (65 %) of degraded cropland in the world, of which 46 % caused by water induced erosion (Oldeman et al., 2017). However, its trend, severity, and extent vary from site to site based on inherent soil characteristics, geological substrates, agro-ecological set ups, and the level of human and livestock pressures. In this regard, Eastern Africa is believed to be the leading region in terms of land degradation problems (Kirui and Mirzabaev, 2014).

The most frequently mentioned causes for land degradation in Africa include, a high and increasing population and economic pressure, over cultivation of croplands, intrinsically fragile nature of resources and ecosystems, high rates and accelerated soil erosion processes, with expansion of refugees settlements due to conflicts and wars, inappropriate land use and management practices, over cutting of vegetations, land tenure insecurity and susceptibility to climate change and variability impacts, among others, which interact over several temporal and spatial scales (Liniger et al., 2011; Kiage, 2013). The land degradation impacts vary from place to place based on geographical characteristics, political and socio-economic contexts (UNEP, 2015, Reed et al., 2015). For example, in Sub-Saharan Africa, land degradation affects close to 2/3rd of the productive land and undermines more than 3 percent of agriculturally derived gross domestic product (UNDP, 2013; Nkonya et al., 2016).

Despite Land degradation remains a serious impediment of development, the adoption of SLM practices is insufficient in Africa. The problem is more precarious in the sub-Saharan Africa where SLM adoption is estimated to be 3% of total cropland (Kirui and Mirzabaev, 2014).

2.3.3 Land Degradation in the Ethiopian Highlands: Persistent Environmental Myths

Ethiopia, with a land area of 1.12 million km^2, possesses a great diversity of natural resources (terrain, climate, soil, flora and fauna) and diverse agro ecological environment. For millennia, Ethiopia has been predominantly an agrarian country where land is a critical resource and smallholder subsistence agriculture plays pivotal role to its socioeconomic development. Agriculture in Ethiopia has long been a priority area and a focus of national policy which was/is expected to drive the overall economic development of the country. The agricultural sector, standing as the base and the building block the economy, provides 46% of the GDP, chief source of livelihood for about 87 per cent of Ethiopia's population and 90% of the export commodity (FAO, 2011).

Although Ethiopian is relatively better endowed with such agricultural potentials in terms of stock, quality and diversity for the production in Eastern Africa, its production potentials is still low, owing to severe land degradation problems, poor water management, limited use of technology, and an underdeveloped marketing system (Zeleke, 2000; Nyssen et al. 2004; Zeleke *et al*., 2006; Kassie et al., 2008;). The problem is particularly critical in the highlands of Ethiopia (>1500m above mean sea level) that constitute approximately 45% of Ethiopia's total land area, 95% of the cultivable area and that support 88% and 75% of human and of the livestock population respectively (Hurni, 1988; 1993, Shiferaw and Holden, 1998; Bewket, 2003, Hurni et al, 2010,). It seems against this background that Meles Zenawi, (the late prime minster of Ethiopia) articulated as *"the agricultural sector remains our achilles heel and source of vulnerability. … Nonetheless, we remain convinced that agriculturally based development remains the only source of hope for Ethiopia"* (Meles Zenawi, April 2000).

Land degradation is considered to be a major cause for the decline of land productivity, pervasiveness of food insecurity, and persistent rural poverty (Pender and Gebremedhin, 2007; Yitbarek et al., 2012). Studies show that Ethiopia annually cost 2-3% of its GDP due to land degradation. If not solved, it continues to be a national constraint that poses strong threat to environmental sustainability and the overall prospects of rural development in the country (Nyssen et al. 2009a; Taye, 2013). When describing severity of land degradation in the country, Hurni (1985) argued that Ethiopia is one of the most environmentally distressed areas in the sub Saharan belt where problem of land degradation is widespread.

Land degradations stems largely from inextricably linked and mutually reinforcing human-induced factors such as deforestation and overgrazing, improper farming practices (e.g. continuous cropping traditions and little use/absence of external inputs) , and the use of crop residues as livestock feed, and animal dung for fuel. In many instances, these have led to soil erosion, loss of soil nutrients, decline in water quality and availability, scarcity in livestock feed, crisis in fuel wood and the overall food insecurity (de Muelenaere *et al.,* 2014; Gessesse et al*,* 2015; Adugna et al*,* 2015; Hurni *et al*, 2015).

These problems are further aggravated by mountainous nature of the topography combined with inherently fragile soils, erosive rains, steep slopes, weak institutions and legal framework, increasing population pressure, vague land use rights, poor community participation, persistent poverty, weak infrastructural development and exacerbated by increasing climate change and variability (de Muelenaere et al, 2014; Belay *et al.,* 2014; Tesfa and Mekuriae, 2014).

Land degradation in the form of gully development; soil fertility diminution, depletion of vegetation cover, deterioration of water resource and decline in biodiversity are the most pressing environmental challenge which remains as a serious barrier to enhance and diversify livelihoods options in the Highlands of Ethiopian (Hurni, 1993; Angassa, 2014; Teshome et al., 2015; Gessesse et al., 2015).

Past studies have indicated that among all forms of land degradation processes, water induced soil erosion is by far the main component of land degradation in the highlands of Ethiopia (Hurni, 1988; Gebrehiwot et al., 2014; Hurni et al., 2015; Haregeweyn et al., 2015). It is the most critical threats to the functions and services of the watershed's resources causing serious social, economic, and environmental problems. Water induced soil erosion leading to loss of farmland (Nyssen et al. 2006), decrease in agricultural productivity (Hurni et al., 2015), declines in soil fertility (Haregeweyn et al. 2008), deposition of sediment in downstream reservoirs (Haregeweyn et al., 2015) and impairs other ecosystem services and functions (Gebrehiwot et al., 2014; Haregeweyn et al., 2015).

Early and contemporary studies carried out to estimate soil loss rate both at plot level (Nyssen et al., 2009a; Taye et al., 2013) and catchment level (Nyssen et al., 2009a; 2009b; Haregeweyn et al., 2012) at various times indicate that soil erosion by water and subsequent land degradation is the major challenge in the highlands of Ethiopia. Nevertheless, there are no consistencies among reports on the extent, amount and severity of the problems suggesting the level of land degradation through soil erosion varies from area to area depending on the population pressure; farming practices, soil types; local rainfall amount and intensity; the terrain nature and agro-ecological set up of the area (Monsieurs et al., 2015).

2.3.3.1 Land Degradation in the Highlands of the Amhara Region: State and Extent

The Amhara National Regional State (ANRS), whose 66% of the total area is highland and which constitutes almost one-six of Ethiopia's total area (BoA,1997), suffer from serious soil erosion and substantial land degradation problems (Birru, 2002; Zegeye et al 2010; Teshome et al, 2013). As per the national erosion hazard assessment result, land degradation in the ANRS is the most severe threats to the wellbeing of the local community and the biophysical environment as it constitutes more than half of the estimated annual soil loss in the country. Every year a large proportion of cropland is abandoned from production of crops due to soil erosion induced degradation. As the national soil erosion assessment reveals that huge tones of soil have been lost from the region annually by soil erosion. Most of which comes from 10% of the high land areas of the region which is categorized under very high erosion hazard.

Land degradation is the result of natural processes and an unintended side effect of human activities. In fact, local communities do not intentionally set out to degrade natural resources, but may degrade it while exploiting it for their sustenance (de Graaf, 1993). As already noted in the previous sections, even though causes of land degradation are multifaceted and varied, climate variability dynamics, rugged terrain features, early settlement, traditional farming systems which are mostly based on cereal crop production (which requires repeated plowing and provides insufficient ground cover against erosive rainfalls), poor livestock management practices (mainly based on open access to grazing lands, woodlands and hillsides), widespread use of crop residues for livestock feed and household energy (accelerates land degradation and soil nutrient depletion), high dependence on wood and other biomass as sources of energy, cultivation of steep slopes and marginal lands, coupled with insufficient investment in soil and water conservation measures, small and highly fragmented holdings and land tenure insecurity have been widely cited in the literature as the causes of most of the observable land degradation menace in the area (Betru, 2003; Bewket & Teferi, 2009; Zegeye et al 2010; Kirui and Mirzabaev, 2014).

Therefore, in the context of this study, land degradation is defined as a decline in vegetation cover, a reduction in productive potential of ecosystem, land cover alteration and biodiversity loss and reduction in other natural resources as a result of natural processes or human activities. Hence, trends in LULC dynamics, soil fertility status, agricultural productivity, the quantity and quality of water, agro biodiversity, livelihoods status etc are some of the vital indicators accepted as the manifestations of land degradation/restoration dynamics. Among others the spatial-temporal changes in vegetation cover is the chief indicators of land degradation-rehabilitation dynamics in this study due to the fact that vegetation covers determines other associated environmental process such as land-atmosphere interaction, surface and sub-surface water resources, soil erosion rates and conditions of local climates.

2.3.4 Land Management Sustainability Indicators and Assessment Methods

Assessing SLM is not an easy task. This is due to the fact that the determination of spatial and temporal boundaries for assessment is difficult. Moreover, selection of indicators to evaluate is not simple and sustainability evaluation requirement long term data which are practically scarce especially for developing countries (Smyth and Dumanski, 1993). Despite these challenges, most literatures have sugested some ideal indicator for the assessement of sustainable land management.

Indicators are pointers which show the condition, quality or state of the environment. Such indicators are used to monitor the sustainability status of land use and management systems and to determine whether the quality of land remains stable, or is declining or improving over time (Bouma, 2002). The literature suggests that the following components are key indicators for the appraisal and monitoring of SLM practices: Land Use/Cover (LULC) Dynamics; status of biodiversity; Water availability and quality; Biomass productivity; Socio-economic conditions; land productivity trends (annual and perennial crops, pastures, trees etc); Soil fertility status; rate of runoff, condition of Soil Erosion and sedimentation (Dumanski and Pieri, 2001).

There are various ways and methods in the literature to assess and monitor the Status of land degradation/rehabilitations worldwide (Lal et al., 1997). However, there is no single best method for assessing land degradation/rehabilitations. The most common approach is the integration of different sources of information. In these methodological approaches, the status and trends of land degradation/rehabilitation dynamics are evaluated based on site-based indicators (e.g. laboratory measurements of samples taken from the field and field measurements), use of geo-spatial data derived from remote sensing (E.g. the use of NDVI signals) and stakeholder perspectives including experts judgment, land users opinion, in-depth interviews and observations on changes in land productivity (Oldeman, 2002; Bai et al, 2008; Liniger et al, 2008).

2.3.4.1 Role of Remote Sensing and GIS in Sustainable Land Management

Remote sensing is the recording of earth's features from space (Jensen 2007) and the analysis of the acquire data visually and through digital image processing (Bryan et al. 2011; Burkhard et al. 2012). GIS is computer-based information system used to gather, store, and digitally represent and analyze location-based spatial and/or non-spatial geographic features essential for change detection and subsequent planning of natural resources management (Weng, 2002; Singh, et al., 2010).

Remote sensing and GIS are, therefore, powerful tools to obtain precise and timely information on the status of the watershed resources before and after the implementation of SLM program, indicating the changed scenario. Remote Sensing technology integrated with GIS has emerged has an efficient, time saving, cost effective and indispensable tool for watershed basised resources management and monitoring activities (Skidmore et al, 1997). Multi-temporal remotely sensed data conjunction with socio-economic not only provide input for better sustainable land management implementations but also help in monitoring its success and progress. It is also important in delineation, characterization, prioritization of erosion prone areas and generation of variety of derived maps of the area of interest (e.g. watershed) (Bryan et al., 2011; Burkhard et al., 2012). As noted by Sepehry and Liu (2006), the nature and extent of the change, and the spatial distribution and relationship of the change need attention when examining the state of natural environment including LULC dynamics using GIS and remote sensing.

2.3.5 The Historical Context of Sustainable Land Management Efforts in Ethiopia

Past evidences signify that the first concern for the loss of environmental resources and the need for the environmental protection were observed during Menelik's regime to solve rising fuel wood crisis which convinced of the need for protection forest resources by the government. For this effect, the mandate for the protection environment was give to the then Ministry of Agriculture, which was established in 1908. According to Mahteme Selassie cited in Rahmato (2001), one of the major responsibilities of the Ministry was environmental protection which included the prevention of the haphazard cutting of trees and safeguarding of all forest's resources. Moreover, despite its contribution was insignificant in preventing and avoiding environmental problems, there were various laws intended to govern the protection and management of natural resources in the country (Bekele, 2008). In these cases, it seems appropriate to mention the 1948 Penal Code of Ethiopia, which prohibits any illegal activities that will have unfavorable consequences upon certain components of the physical environment and public health.

Although environmental conservation movement and natural resources related legislation has been issued since 1960s (Rahmato, 1998), the history of institutionalized approach to land use management practices, particularly SWC activities, has gained attention since the 1970s (began during the Derg regime), as an emergency response to the drought episode of the northern part of Ethiopia to which land degradation was recognized as one of an underlying cause (Kruger et al., 1997; Zeleke *et al.,* 2006; Amsalu, 2006; Haregeweyn, et al., 2015; Gebregziabher et al, 2016). This led to the establishment and joint operation of the Relief and Rehabilitation Commission. As a result of this teamwork, conservation efforts began in Wollo (where the study area lies) and other famine affected regions through Food-For-Work incentives to mobilize affected farmers for construction of mainly physical SWC structures supported by various development organizations Such as European Economic Commission, UNDP and FAO (Shiferaw and Holden, 1998; Wegayehu and Lars, 2003). Furthermore, land reform, which come to exist in the mid of 1970's and formation of Peasant Associations (PAs), were important opportunities to mobilized labor and assigned local responsibilities to install SWC measures on degraded landscapes (Shiferaw and Holden, 1998).

However, until the late 1990s, the programs were mainly focused on arresting soil erosion using physical SWC measures and the implementation approach was government-initiated and incentive based (i.e. food-for-work) command approach with limited participation of local communities which eventually led to its failure. (Gebregziabher et al, 2016).

In recent years, particularly since early 2000s, the need for SLM has come at the forefront of national development agenda as major responses to food insecurity challenges and degradation of natural resources. For example, to enhance community participation and implement locally managed solutions to local environmental challenges, the Ministry of Agriculture and Rural Development of Ethiopia prepared and send out community-based Participatory Watershed Development Guideline in all parts of the country (Desta et al., 2005; UNDP, 2013).

2.3.5.1 Reasons for the Failure/Limited Success of Previous SLM Efforts in Ethiopia

Evidence from existing empirical literature review shows that despite SWC practices has the long history; the success of the results in achieving the intended goal has been relatively slow in Ethiopia. The major constraints which are frequently mentioned either for total failure and/or limited success of efforts over the last few decades are attributed to a wider range of cultural, institutional, political, economic and ecological challenges such as implementation of wrongly planned and poorly defined natural resource management policy, top-down approach with inadequate participation of local communities, emphasis on short term solutions rather than long term sustainability, shortage of skillful man power, ignorance of the interests of local communities, poor linkages and integration of rural livelihoods that goes beyond mere soil conservation activities, lack of commitments by the stakeholders to address the problem, inadequate scientific approach and lack of technical knowhow and a host of other factors (Shiferaw and Holden, 1998;1999; Zeleke, 2000; Betru, 2003; Bewket, 2003; Bekele and Drake 2003; Gebremedhin and Swinton, 2003; Rahmato, 2004; Desta *et al.,* 2005; Kassie *et al*., 2010).

1. Top-Down Planning Approach and Inadequate Community Participation

Historically, the governments have been commonly assumed as custodian of the land and responsibility for avoiding misuse, the overall choice of technologies and implementation strategies to halt land degradation and uphold SLM were the duties of the government and their collaborators (UNDP, 2013; Gebregziabher et al, 2016). Most of these top-down approaches, which was widespread during the 1970s and 1980s were pre-planned and rigid approach and executed mainly through food for work program as a one-size-fits-all type of strategy which undermined local participation and collective action in identifying problems and finding solutions. Consultation of stakeholders in planning, sites selection, and choice of technologies, implementation, management and impact evaluation of the recommended SLM technologies were insufficient. These technologies were prescribed without creating awareness and building necessary capacity about their technical requirements at community level and develop trust among land users. Since these technologies were disseminated without considering the local contexts, specific farming systems, local knowledge, experience, preferences and priorities, their long-term sustainability was more likely to be achieved. This mode of intervention was neither effective nor efficient. In some cases, these technologies instead of addressing community needs and improving household level economy, they further aggravate land degradation problems (Mitiku et al., 2006). It was against this public discontent that a large scale of forest areas was apparently cut down and conservation structures were completely removed and/or partially destroyed by the farmer themselves following the political repercussion and the downfall of the Derg regime in 1991 (Rahmato, 2004).

2. Focus on Short Term Solutions Rather than Long Term Sustainability

The intervention strategies were tailored towards building physical SWC structures instead of using and/or integrating other components of sustainable land management. Moreover, the primary focuses were reducing soil erosion rather than enhancing agricultural production, quantity rather than quality and sustainability, size of area coverage/ quota of interventions rather than impacts, construction of new structures rather than maintenance of existing and immediate solutions rather than sustainability issues. Hence, the intervention strategies were not successful as most the activity were not according to community's priorities (Bekele and Darke, 2003; Mitiku et al., 2006).

3. Problems Associated with the Implemented Technologies

To achieve SLM, appropriate technology needs to be developed, transferred and adopted. For successful adoption of recommended technologies by the land users, the chosen technologies should be more farmer friendly, Suitable to locality, easy to construct and maintain, productive, adapt to climatic variations, effective in dropping soil erosion and improving soil moisture status, flexible and compatible with existing specific farming practices and wel-suited to local environmental context and should address local socio-economic constraints (Lee, 2005).

The previous program has been criticized for not conducting site-specific plans that takes into account labor demand; productivity impacts, compatibility etc. For instance, building physical structures are labor intensive technologies which are more labor demanding. As the focus was only to control the loss of soil, the productivity impacts of implemented measures were not considered. Moreover, the structures were incompatible with the existing farming systems and to locate the structure, scarce productive lands will be lost out of production and thereby yield falls at least in the short term (Kassie et al., 2008; Adimassu et al., 2014). Furthermore, the structures were criticized for creating favorable conditions for harmful weeds and various rodents (Zeleke et al, 2006).

In this line, Kerr and Sanghi (1992) highlight the following preconditions for the successful up scaling, adoption and sustainability of land management technologies. First, since each local situation is different, the selection of technology should be apposite to the existing agro ecology, soil type, topography, climate, etc. Second, the design, implementation and maintenance of the proposed technology should not be too complex. Complexity increases the learning costs for Farmers. It should be easy to implement in terms of time and resources of farmers. Third, it should be integrated with farmer's indigenous knowledge and practices.

Correspondingly, Lutz et al., (1994) pointed out that land users favored and widely adopted without external incentives if proposed technologies " combine components which are familiar to farmers; are compatible with their farming systems and social activities; are simple, of low cost, and do not require finance for implementation; provide short-term economic returns; do not require additional labor; are adaptable to specific site conditions; can be adapted and adopted sequentially as the farmers' experience of the technology increases".

4. Land Tenure Insecurity

Land is the most valuable natural heritage of mankind. It is also important asset that determine the wealth of the nation and economic development of the country. Land tenure refers to the arrangement of land holding under which rights to land and land-based resources are defined and institutionalized. In Ethiopian context, land tenure arrangement has been one of the debating topics among scholars and politicians for decades on whether the arrangement motivates or discourages investment on land improvement.

On this line, there are divergent research reports that highlight the connection between tenure security and SLM. Some studies revealed that secured land tenure enhance land holders's vision and decision for long term land management investments. More secure right or ability to use land in the long-run promotes SLM investments (Feder 1987). Land tenure insecurity and limited transfer of rights, on the hand, can seriously influence sustainable land management practices and lead to depletion of resources by undermining land users' incentives, confidence and trust on their holding. There is considerable evidence that land tenure insecurity has slowed down investment in SLM practices in Ethiopia. If the land users are uncertain about the future gains that arise from land management efforts, they will have no interest in maximizing their long-term investment and properly manage the land (Gebremedin and Swanton, 2003; Woldeamlak, 2003; Kirsten et al., 2009). In contrast to the above findings, other studies have shown that land tenure insecurity may motivate land holders to engage in long-term investments (e.g. plant trees) as a means of claiming ownership and tenure security (Place and Otsuka 2002). However, Amsalu (2006) in his study on Beressa watershed, central highlands of Ethiopia, reported insignificant causal link between tenure security and SLM.

2.3.6 Current Scenario of SLM Practices in Ethiopia

The lesson learned from the technical, socio-economic and political deficiencies that causes the failures of many past efforts, the government of Ethiopia acknowledged the needs and value of different enabling policies environments, regulatory framework, strategies and implementation guidelines that favor stakeholder engagement and cooperation and an integrated and an interdisciplinary approach in order to address issues of land degradation problems and improve the status of rural livelihoods through an efficient and effective SLM practices (Desta *et al.*, 2005).

2.3.6.1 The Enabling Environment to SLM under the Current Government

Investment in sustainable land management requires a supportive enabling environment. An enabling environment is a set of interrelated issues such as legal and regulatory framework, political and governance factors, socio-cultural characteristics, funding conditions, external partners and actors that impact on the implementation of SLM in a sustained and effective manner (World Bank, 2008; Haileslassie et al, 2009; MoARD, 2010).

For this study, an enabling environment refers to policy, legal and institutional frameworks, land use and tenure securities, authentic information, public awareness, institutional support, participatory approach and suitable human capacity building and enhancement of technical knowledge. In order to provide long-term solutions to land degradation problems and to create an enabling environment for the success of SLM in Ethiopia, the incumbent government has issued several strategy and policy documents that have bearing on proper use and management of natural resources both at national and regional levels. Some of these policy framework and/or strategies that highlight the need for sustainable land management include: The Environmental Policy (1997), Rural Development Policies and Strategies (2003), Ethiopia's Agriculture Sector Policy and Investment Framework (2010–2020), The Federal Rural Land Administration and Use Proclamation (*No. 456/2005),* The National Plan for Accelerated and Sustainable Development to End poverty (which was implemented over the five years period (2005/06–2009/10), Growth and Transformation Plan one & two (GTP I and II), Community-Based Participatory Watershed Development Guideline and Ethiopian Strategic Investment Framework for SLM (ESIF-SLM) (2009-2023), to list but a few.

Moreover, there are several other national natural resources related policies and strategies with direct relevance to the implementation of sustainable land management that have been put in place within the country. The most prominent of these include the conservation strategy of Ethiopia (April 1997); The national policy on biodiversity conservation and research (1998); The Ethiopian Water Resources Management Policy (1999); the Productive Safety Net Program (Since 2005); Forest Development, Conservation and Utilization Policy (2007); Soil Fertility Research and Management Road Map (MoARD, 2010);); Ethiopia's Climate Resilient Green Economy strategy (2011); Ethiopia Soil Information System (2011); strategy for the Transformation of soil Health and Fertility (2013) and others.

As part of the global community, the government also approved and signed numerous important global environmental conventions and treaties such as the the UN Convention to Combat Desertification (UNCCD), Convention on Biological Diversity (CBD) and the UN Framework Convention on Climate Change (UNFCCC) that have significant contributions to promote SLM practices. Moreover, Ethiopia is a pilot country for UN and World Bank REDD^{+} initiatives and Clean Development Mechanism (CDM) of the Kyoto protocol since 2008 (Ayana et al, 2013).

2.3.7 Factors Influencing Sustainable Land Management Decisions and Actions

Studies on the factors affecting SLM decisions began to emerge, for the most part of the world, around the mid of the twentieth century (Ervin and Ervin, 1982). Since then, several empirical studies have evaluated the factors affecting the acceptance and sustained use of SLM technology in various countries of the world at different times. Accordingly, various set of factors that influence farmers' decision to accept, reject or sustainably use of SLM practices have been identified.

Among many others, some of these factors studied were: personal factors (characteristics of the household head like age, educational attainment, gender, farming experience , family size and perception); Physical features of the farm (farm size, proximity, accessibility, slope, soil fertility and erodiblity); economic and financial factors (off-farm income and livestock ownership); institutional factors (land tenure security, access to training and support, effort of development agents, communication channels, social participation etc…) , attitudinal factors and characteristics of the technology (Shiferaw and Holden, 1998; Gebremedin and Swanton, 2003; Woldeamlak, 2003; Bekele and Drake , *2003;* Amsalu, 2006).

2.4 Analytical Framework

There are numerous relevant conceptual frameworks that help to understand human-environmental interactions. However, depending on the specific objectives, this study was guided by integration of two widely-known analytical frameworks; namely, the DPSIR and Sustainable Livelihoods frameworks. The elements of these two frameworks help integrate biophysical and human dimensions of land degradation/SLM impacts on the physical environment and community livelihoods (Schwilch et al, 2011).

2.4.1 The Driver-Pressure-State-Impacts-Responses (DPSIR) Framework

The DPSIR framework is a theoretical and empirical tool which describes the various causal chains and links between the local environment and various human activities in a broader socio-economic context and helps develop appropriate management responses. Its root goes back to the stress response framework developed by statistics Canada in the 1970s. Later on, it evolved into the Pressure-State-Response (PSR) model which was initially proposed by the Organization of Economic Co-operation and Development (OECD) in 1993 for environmental indicators. The DPSIR framework in its present form was developed by the European Environmental Agency (EEA) for the first report on the status of the environment and for developing environmental indicators in 1999, which led to the DPSIR framework as it is known today (EEA, 1999; 2005).

The DPSIR framework **(Fig 2.1)** has been widely adopted as a systematic approach to evaluate the complex and multifaceted human-environment interactions by assessing the links among biophysical and socioeconomic drivers, resulting pressures on environment, state of the environment, impacts on biophysical environments and local livelihoods, and local responses to combat environmental degradation and improve livelihood options (Song and Frostell, 2012). The general concept behind DPSIR framework is that any natural (bio-physical) or human-induced (socio-economic) driving forces which directly or indirectly exert certain pressure on the natural environment and, as a result, on the State of the environment (biotic and abiotic constituents) changes. These forces can vary spatially from local to global context (Pullanikkatil et al., 2016).

These changes may have positive and/or negative environmental and economic impacts that may elicit a set of societal and government reactions to perceived changes in the environment. Responses for remedial actions may be emanated from policy and/or local levels and tries to address the pressures or attempt to maintain or improve the state of the environment. Responses have to be technologically feasible, ecologicaly sustainable, economically viable, socially acceptable, legally compatible, and administratively achievable. (EEA, 1999; Costantino et al, 2004; Kristensen, 2004).

For this research, the DPSIR analytical framework was adopted for the following reasons. First, the framework has been widely recognized as a valuable approach for examining various aspects of human-environment linkages and provides helpful insights on land resources degradations and efforts devoted to halt land degradation and restore degraded lands through contemporary participatory integrated watershed management interventions and the effectiveness of the responses (Song and Frostel, 2012). Second, the framework has been widely used and tested in many parts of the world to assess human-environment interaction and for integrating the ecosystem services and the sustainable livelihoods (Walmsley, 2002). Third, it enables to appraise the present status, to make retrospective analysis and even to predict future scenarios over range of spatial scales. Hence, the framework enables to understand the complexity of human-environment interaction and resulting environmental change both spatially and temporally that go beyond simple analysis of land use/cover change (Pullanikkatil et al., 2016).

2.4.2 Sustainable Livelihoods Framework (SLF)

A livelihood encompasses the capabilities, assets (physical and social resources) and activities essential for survival (Chambers and Conway, 1992). Scoones (1998), stated that "a *livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets, while not undermining the natural resource base which provide sustainable livelihood opportunities for the future generation*". The SLF, developed by the DFID of UK, has become one of the most famous frameworks for investigating the interactions among biophysical, socio-economic, institutions and their legal instruments and local livelihoods.

As noted by Scoones (1998), SLF provides a holistic approach to analyze investment decisions within the context of different livelihood options. The SLF enable to capture the many factors that influence people's livelihoods and helps to recognize main concern for action based on the needs and interests of the community. The impacts components can be in both directions i.e. many pressures leading to land degradation arise from the activities of land-users and land degradation/sustainable land management causes impacts on land-users' livelihoods. In this regard, Sustainable Livelihoods framework is used to help understand both the drivers and pressures leading to land degradation/sustainable land management and the impacts of land degradation/sustainable land management on people.

Sustainable livelihoods framework comprises five components that contribute to livelihoods. These are livelihood assets, institutional (mediating) processes including organizational structures, resilience or vulnerability context, livelihood strategies and livelihood outcomes (Scoones, 1998; Kollmair et al., 2002). The framework assumes that land users operate in a context of vulnerability (shocks trends seasonality), within which they have access to certain livelihood assets (human, natural, financial, social, and physical capital). Access to assets and decision-making processes are influenced by government policies and institutional environments. People undertake combination of activities to achieve livelihood objectives through various livelihood strategies. Outputs of livelihood strategies may include increase in income of housholds, improved in community well-being, enhanced food security status, decrease vulnerability and use of natural resources in a sustainable manner (Scoones, 1998, DFID, 2001).

The sustainable livelihoods analytical framework was adopted for this research for the following reasons: First, the framework enables to fill some gaps which are not address through DPSIR framework. Second, it enables to understand the diversity and dynamics of public differentiated assets, awareness, precedence, and natural resources use practices; livelihood strategies and prospects of progress. Third, it allows investigation of various human-environment links, including historical perspective of the biophysical, social and political dynamic of environmental sustainability (DFID, 2001).

According to Nkonya et al. (2008), there is a link between sustainable livelihoods and SLM practices. The link assumes that land management decisions are influenced by the quantity and quality of assets to which households have access. These include, but not limited to, natural capital (land quality and size of landholdings, water resources, fragmentation, land tenure, distance, access to sharecropping land and other environmental resources), physical capital (household asset, livestock ownership, production equipment, accessibility to roads and other infrastructures), human capital of the household (labor availability, skill, health status physical capability of individuals and education status at the household level, family size etc), financial capital (the habit of household savings, off-farm employment, relief aids, credit access (it can be from formal and/or informal sources), remittances and other financial sources), social (technical assistance , local social institutions that promote SLM like *Iddir (Qire), Mahber/Senbete, 'Debo/Jigie'* and '*wenfel/Mekenajo'*; informal networks; mutuality of interest; enabling policy environment for community participation; political commitment and good governance; adherence to rules and regulations including community by-laws.

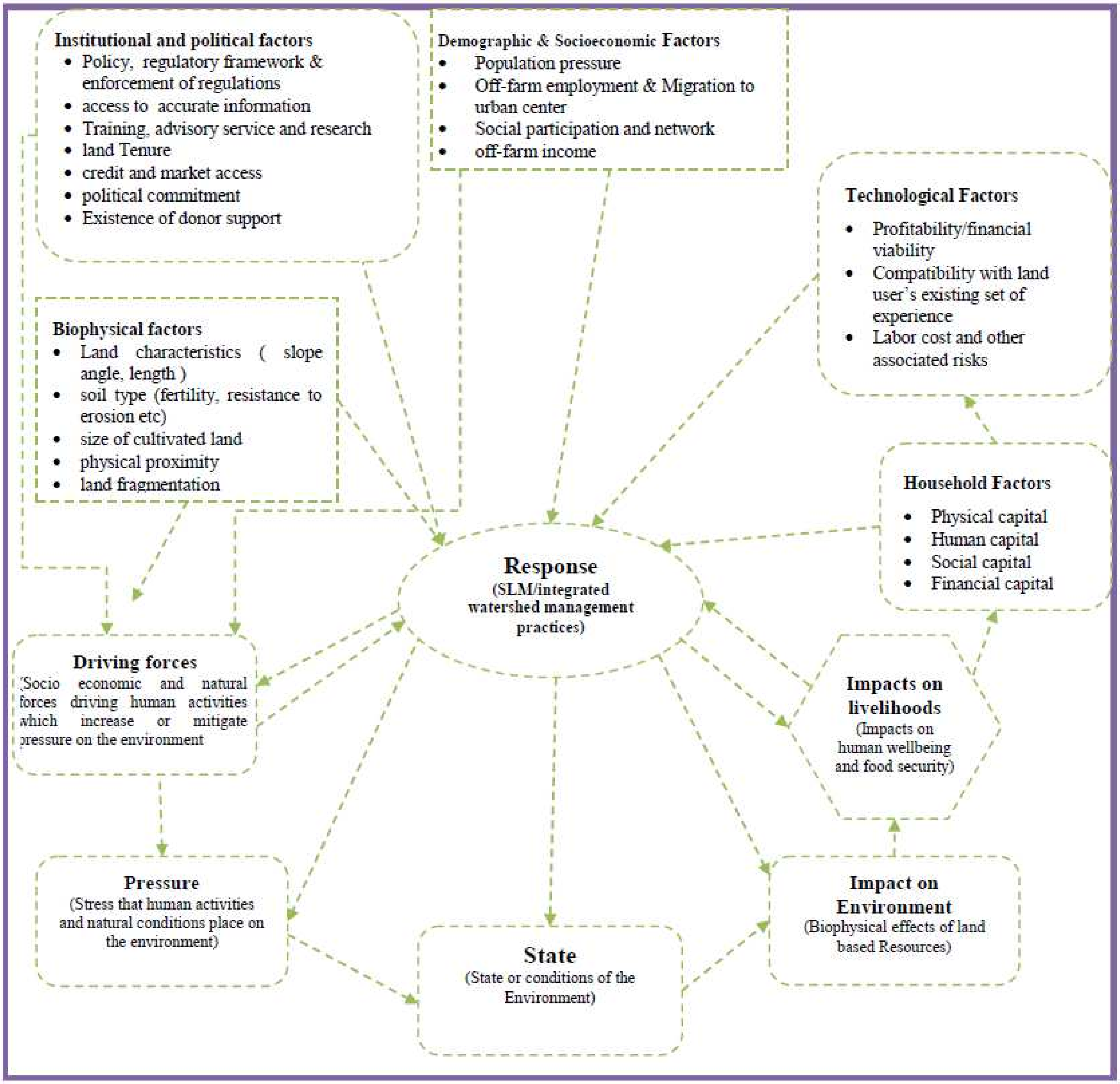

Figure 2. 1: Analytical frameworks on land degradation-rehabilitation dynamics
(Modified from EEA 1995; UNEP, 2006; 2007; FAO, 2011)

CHAPTER THREE

3. RESEARCH METHODOLOGY

This chapter presents the overview of the study area and the methodologies used to attain the objectives of the study. The first section describes the research areas (focused on the watershed). The second sections outline research philosophy, the research design, types and sources of data, specific methods of data gathering, sampling techniques' and procedures, how the collected data was presented and analyzed, and lastly issues related to the ethical considerations that were made during the research process.

3.1. Profile of the Study Area

3.1.1 Location and Size

Geographically, the study watershed entirely lies within Tenta District, South Wollo zone, Amhara region of Ethiopia. It is situated between 10°56'52" to 11°13'26" north latitudes and 39°06'10" to 39°18'53" East longitudes (Fig. 3.1). It is located about 520 km north of the capital city, Addis Ababa and 120 km west of Dessie town, the capital of South Wollo Zone. Physiologically, the study area is located in a relatively inaccecible, degraded and drought prone area of the Upper sub catchment of the Beshillo River, Northeastern Highlands of Ethiopia. The watershed covers a total land area of 23970 hectare (nearly 240 km^2).

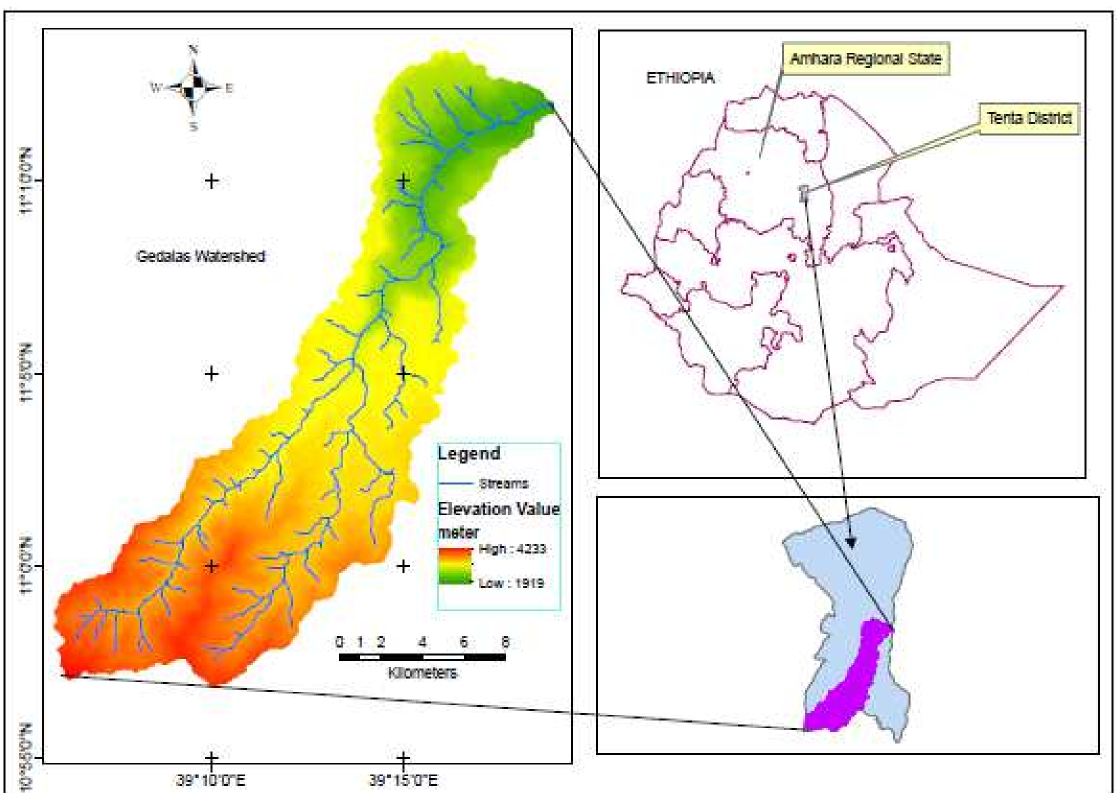

Figure 3. 1: Map of the Study Area

3.1.2 Drainage networks and Topography of the study area

Like many other parts of the country, the diverse terrain features observed today is a result of initial geomorphological processes (volcanic eruptions and/or tectonic movements) and sequential events (weathering, mass wasting, geological /accelerated erosion and deposition). The topography of the watershed is diverse that range from almost flat areas to undulating and steep slope escarpments. Most of the watershed is characterized by rugged and strongly dissected mountainous landscapes with steep slopes and deep ravines which make the area highly susceptible to soil erosion risks. The topography stretches over a length of roughly 36 km and a width of around 8km.

The altitude of the watershed varies over short distances and ranging between 1919 and 4233 m a.s.l with the average elevation of 3163 meters. The highest and lowest elevation spot of the watershed are found at Adebabay (at the peak of Guassa) and Adela (outlet of Gedalas river), respectively. The slope of the watershed gradually decreases towards north-east direction. The watershed is drained by two major rivers (Gedalas and Kechina) and numerous small streams which generally form part of the western wings of upper Beshillo catchment of Blue Nile basin. Most of the streams are highly seasonal and are impassable immediately after the periods of heavy rains, while at the driest season of the year they hold no water at all. The Watershed has a relatively elongated form, and the drainage pattern is rectangular with a tendency to be dendritic (Fig. 3.2).

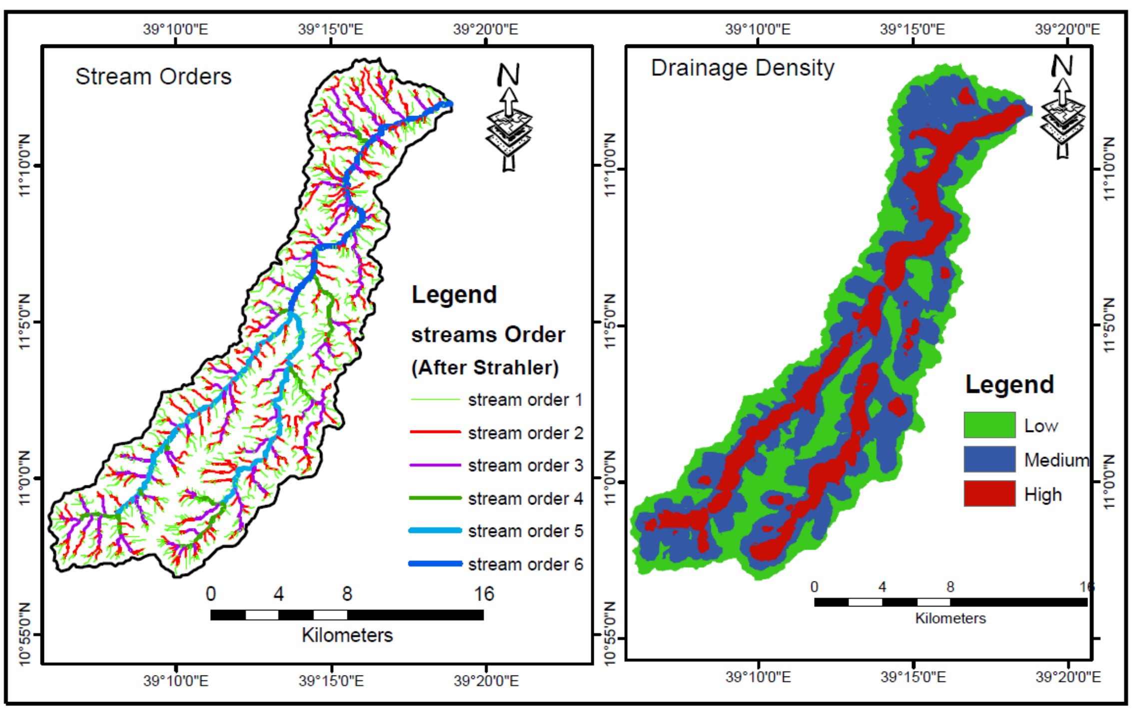

Figure 3. 2: Stream orders and drainage density of the watershed

Based on FAO (2006) slope classification systems derived from 30 meters resolution DEMs (analyzed using Arc GIS 10.3 software spatial analysis tools), the watershed constitutes areas covered by slopes ranging from less than 5%, to above 60% (Table 3.1).

Table 3. 1: Slope gradient classes of Gedalas watershed

Slope class (%)	Area* (hectare)	Percent of the Total* (%)	Description
0-5	1098	5	Flat to Gently sloping
5-10	2790	12	Sloping
10-15	3161	13	Strongly sloping
15-30	8832	37	Moderately steep
30-60	6663	28	Steep
>60	1426	6	Very steep
Total	23970	100	

*Numbers are rounded to the nearest whole numbers.

Slope status is one of the parameters that indicate degree of soil erosion and hence how much and which part of the watershed is suitable for agricultural activities and which part is not. Slope form, steepness and length influences level of runoff and erosion. In this line, Hurni, (1988) suggests that land with slopes gradient less than 15% is mainly fit for agriculture. However, land with slopes less than 15% for this watershed accounts for only 30% of the entire area (Table 3.1) and even some portion of these lands are covered by rock outcrops and extremely shallow soils which are not conducive for cultivation. Given such rugged landscape, cultivation in such sloppy area has been inevitable and practiced for many years. With growing population, land becomes scarce and thus more and more marginal lands and hillsides have been turned into farms. Recently, cultivation has also been pushed up into the high *Wurch* zone which was not conducive for farming so far. The implication of this is that the watershed requires various kinds of land management practices including SWC measures.

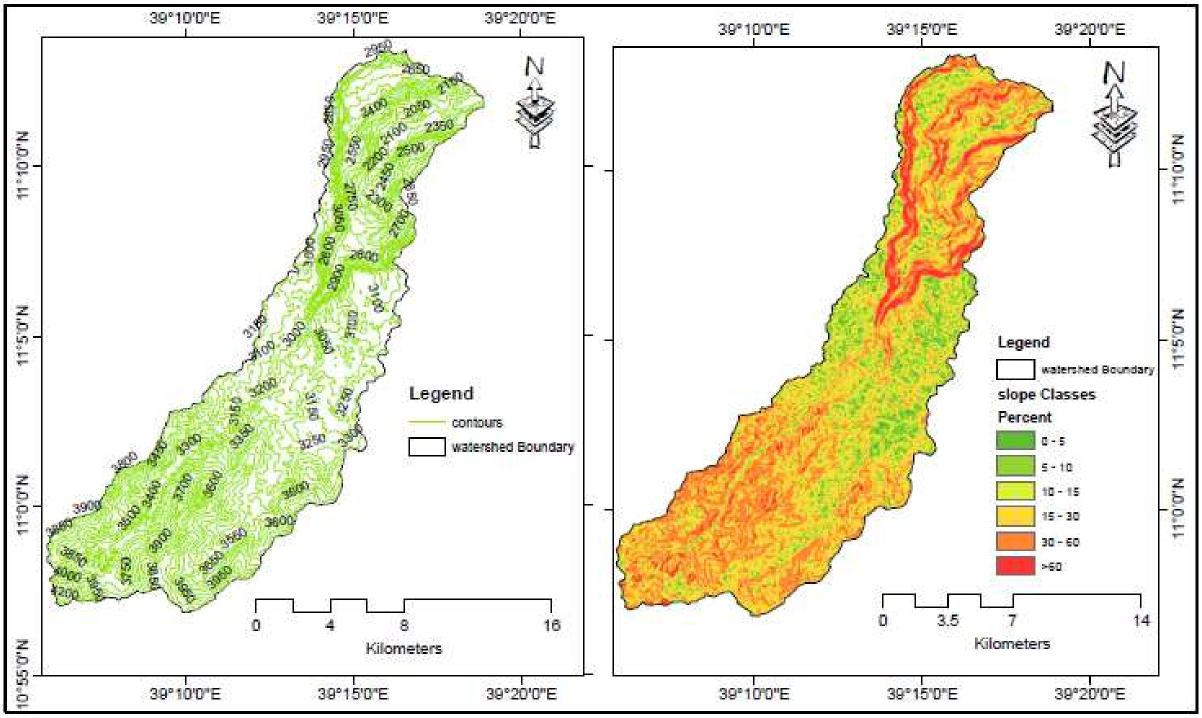

Figure 3. 3: Elevation and Slope Map of the Gedalas Watershed (Source: Computed from Ethio-GIS data base)

3.1.3 Geology and Soil Types

Geologically, there is limited available information about the geology of the watershed itself, as no geological surveys have been conducted on a watershed scale. However, as it has been observed from broad geological map of Ethiopia (1:2, 000,000 scales), it is believed that the bedrock characteristics of the watershed belong to tertiary volcanic eruptions (Oligo-Miocene Trap Basalts) and is comparable to the majority of landscapes in the central and northeastern highlands of Ethiopia (Tefera et al., 1996). As noted above, its surface morphology is an outcome of part of the uplifting of the Arabo-Ethiopian landmass and the subsequent tectonic episodes and geomorphic processes that are taking place in the past geologic times (Mohr, 1971).

Soil units covering the area are primarily originated from Trappean volcanic series. However, no in-depth soil study have been carried out in the area except the FAO/UNESCO (1984) small scale soil survey (1:1000, 000) at the national level and as per digital soil data base soil map (1:250,000) of the Blue Nile river master plan produced by Ministry of Water Resources, the major soils types covering the watershed includes Lithic Leptosols (62.1%), Eutric Cambisols (18.4%), Eutric Regosols (12.5) and Eutric Vertisols (7%). Leptosols are the dominant soil types covering large areas (14879 ha) of the watershed and occur on steep slopes, crests and ridges, interspersed with stones and rock outcrops. These soils are shallow, coarse in texture, low in fertility status and low in moisture holding capacity suggesting the existence of high soil erosion and therefore this soil unit is less suitable for crop production (Yimer, 2005). Vertisols dominate in relatively small flat topography of the watershed. These soil units have a very hard consistence; and they crack deeply and widely upon drying and become very plastic and sticky when wetting. It also becomes waterlogged and difficult to work when wet. The local people have traditionally named such soils as "*Walka/Mererie Afer*".

Color of the soil varies from very dark grey to dark grayish/ reddish brown. However, two types of soils color dominate most of the agro-ecological zones of the watershed: Black and Dark-brown. Black soils dominantly found in the high altitude and plain areas of the watershed while Dark brown colors predominate down steam parts particularly in the steep slopes or mountainous areas of the watershed.

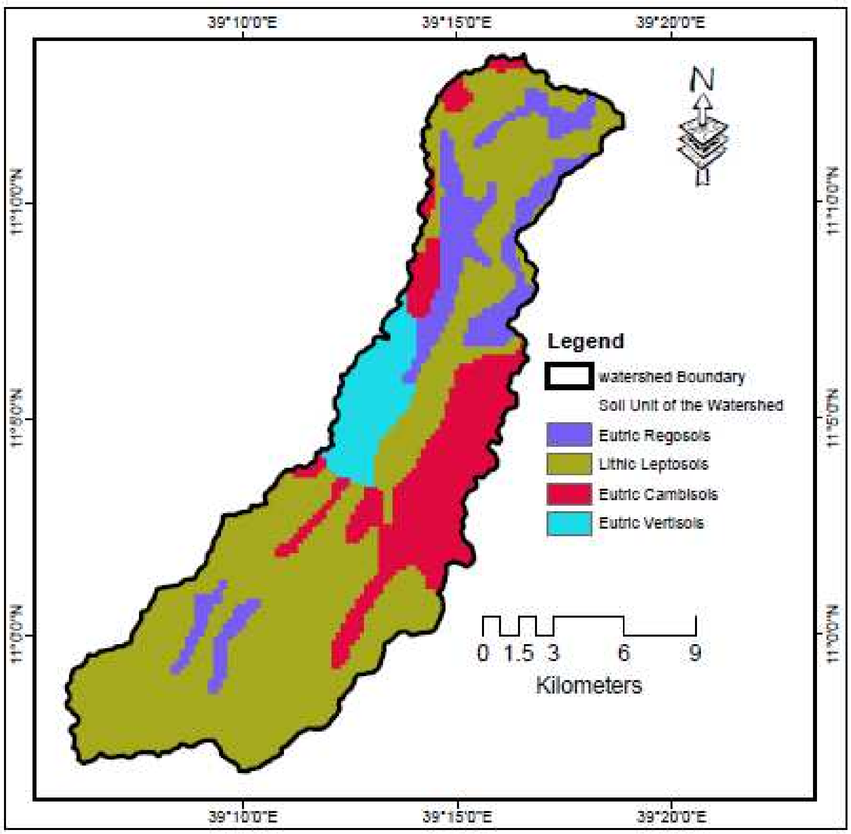

Figure 3. 4: Dominant soils types of the watershed

(Source: extracted from digital soil map of the Blue Nile river master plan)

3.1.4 Agro-Ecological Zones and Climate

Though small in size, the range of elevation of watershed is high and is, therefore, characterized by a relatively high degree of agro ecological diversity. Based on traditional agro-ecological classification (Hurni, 1998), the watershed is sub classified into three main agro-ecological belts; namely, Wurch (Afro alpine), Dega (highlands) and Woina Dega (midland) zones.

Table 3. 2 : Agro Ecological belts of Gedalas Watershed and Area that each belt occupies

Agro-ecology	Altitudinal Range (m a.s.l)	Area in ha	Percentage (%)	Ideal conditions for the production of
Woina Dega (Midland)	1919-2300	1614	7	Teff, Sorghum, Wheat, Pulses and oilseeds
Dega (highlands)	2300-3200	10682	45	Teff, Wheat, Barely, Pulses and oilseeds
Wurch (Afro/sub afro-alpine- meadows)	3200-4233	11674	49	Barley, potato (solanum tuberosum L.) and Engido (Avana spp.)
Total	1919- 4233	23970	100	

Early studies suggest that there is no rainfed crops expected to grow in the altitudal belt above 3600 meter of the afro-alpine areas due to frequent frost challenges (Bantider, 2007; Hurni 1998). However, it was observed in this study that cultivation of crops slowly encroached beyond the expected upper limit. Accordingly, rain fed crops such as Barley has been witnessed above an altitude of 3800 meters in the watershed. This is probably due to the effects of global warming which leads to an upslope shift of the agro-climatic boundary (Nyssen et al., 2015).

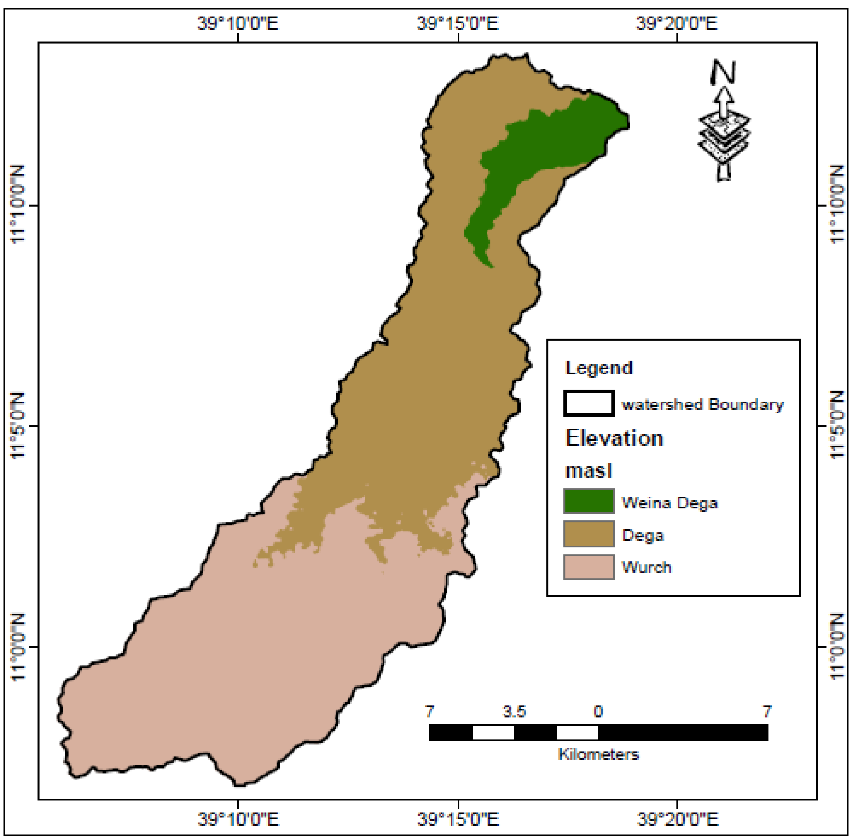

Figure 3. 5: Agro ecological belts of the watershed

(Source: Computed from Ethio-GIS data base)

Although the watershed lies entirely within the tropics, its climate is counterbalanced by the elevation of the land. There are three broad seasons throughout the year in the study area: the *Bega* (dry months), *Belg* (small Rainy months) and the *Kiremt* (main rainy months). The main rainy season usually runs from mid June to early September and the dry season prevails from October through February up to May. Within these broad categories, there is a short rain (the *belg* rain*)* which occurs from mid February to the beginning of May. Both the *Belg* and *Kiremt* rains have greater importance in the study area although the timing of onset and duration of the rains can vary considerably.

Belg rains are more important for those living on the high *Dega* and *Wurch* agro ecological zones whereas those on the *Weyna Dega* and *Dega* areas depends on both the *Kiremt* and *Belg* rains. The Belg rains are important for planting long maturing crops (maize and sorghum) and short maturing crops (barley) in the lower reach and upper parts of the watershed respectively. The *Belg* season is also imperative for refilling waterholes and rivers as well as availability of pastures for livestock. However, inter-annual variability of both *belg* and *Kiremt* rainfall is a typical characteristic of the area. In some seasons of the years, *Kiremt* rains are intensive while in the other seasons it is characterized by dry spells, late onset, interruptions and/or early cessation which all results in risks of climate related shocks such as severe shortfall of moisture particularly during flowering and maturity stage of the growing seasons, resulting in substantial decline in yield or even total harvest failure. The *Belg* rains are unpredictable, small, and erratic and often fail completely too.

This annual and seasonal variation of rainfall in Ethiopia is governed mainly by seasonal north–south oscillation of the ITCZ. These seasonal rainfall patterns have a major influence on agricultural production, as rainfall is highly varied across the months of the year.

Though rainfall and temperature values vary spatially (both vertically & horizontally), the nearest metrological station's (Ambamariam meteorological station located on the edge of the watershed) climate data, was used as representative of this study site. Since there is no metrological station within the watershed, temperature and rain fall analysis of the study area depends on Tobler's 'first Law of Geography' (Sui, 2004) which asserts the important aspect of the real world from a geographic perspective as "*everything is related to everything else, but near things are more related than distant things*". Moreover, it should be noted that, since some portions of the study watershed lies above or below the elevation of the location of metrological station, there may be certain variation on both temperature and rainfall values and distributions.

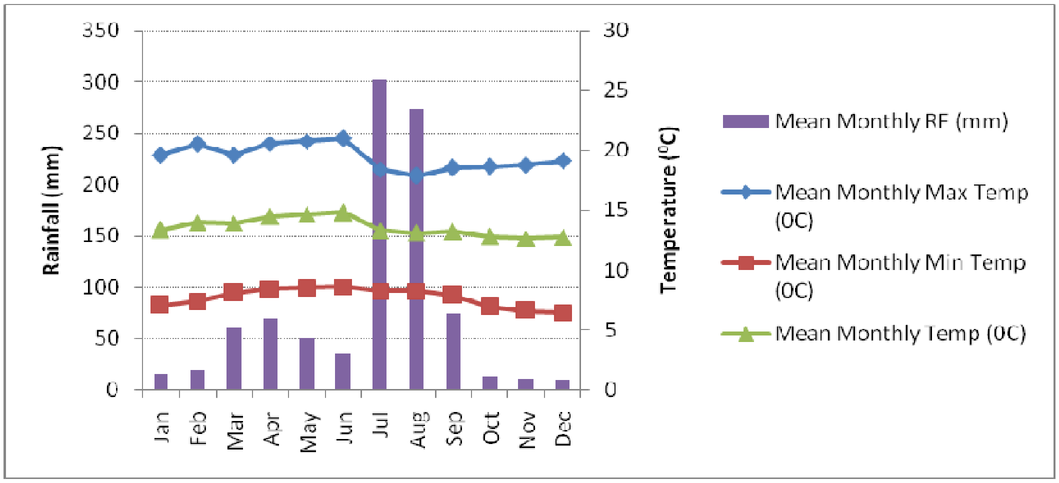

Figure 3. 6: Mean monthly max. and min. temperature and mean monthly rainfall records 1984-2014

The mean total annual rainfall of Ambamariam meteorological station (which is found at an elevation of 3000 m in South Wollo, Ethiopia) **for** the observation period is 930 mm with the minimum of 592 mm (in 1984) and a maximum of 1216 mm (in 1988) which results high inter annual variability. As data from this station shows, nearly 75% of the rain occurs in wet (*Kiremt)* season and 21 % in the *Belg* season. The highest average monthly rainfall (303mm) was recorded in July; the lowest (10 mm) in December. The rainfall value shows annual variation both in terms of amount and distribution. The coefficient of variability of rainfall was calculated at 14.62% implying inter annual variability of rainfall is a regular characteristic in the watershed. As it can be noted from the standardize rainfall anomaly (Fig.3.6), rainfall was deficit for about 15 years while relatively excess rainfall occurred only for about 14 years of the observed periods in the study area. This implies there were several meteorological drought periods in the watershed and its surrounding.

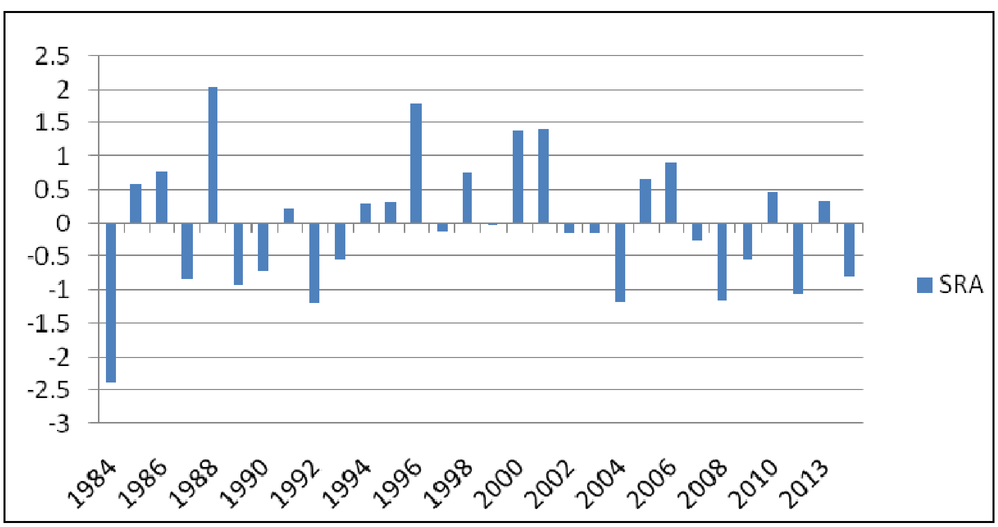

Figure 3. 7: Standardize Rainfall Anomaly (SRA) (1984-2014)

The minimum monthly average temperatures range from 6.4 - 8.6 °C while the maximum values stretch from 17.9 - 21 °C. The highest and the lowest temperatures of the watershed occur in June and Augus, respectively. The annual average temperature of the area is 13.6 °C.

Apart from the empirical data, focus group discussants and key informant interviews reveal that rainfall and temperatures are variable. Moreover, the local communities perceived that sporadic frost, late onset, shortage and/ or complete failure of *Kiremt* and *Belg* rainfall are the major impediments of agricultural activities in the study areas.

Local communities also perceived that gradual change in rainfall and temperature has reduced length of growing period. This situation not only reduced crop productivity but also forced the farmers to grow early maturing crop varieties and to change the types of crops growing on their farmlands. As pointed out by key informants from the cooler parts of the watershed, the number of barley varieties grown in the area has declined and only few varieties remain. This clearly implies gradual loss of traditionally known agro biodiversity in the watershed due to the effects of climate change.

3.1.5. Vegetations

Although there are different terrain features, agro ecological zones and associated climatic variations, the overall vegetation cover of the watershed is very poor. Even if some patchy remnants of ancient tree species are rarely visible in sacred sites such as in and around churches (consecrated land (*Bewigz Yetekebere Dun*), mosque compounds and graveyards (e.g. Wijjib[2]), there is no dense forest cover in the study area.

However, there are still different dispersed indigenous and exotic tree species including patches of eucalyptus trees which is planted by farmers and government campaign programs, various species of scattered woodlots along hillsides and unique afro alpine vegetation types at the highest parts of the watershed.

Some of the isolated tree species found in the study watershed include *Girar (Acacia abyssinica), Wanza (Cordia Africana), Bissana (Croton machostachys), Bahirzaf (Eucalyptus globulus and Eucalyptus camaldulensis), Kitkita (Dodonaea anguistifolia), Weyra (Olea europaea), Koshim (Dovyelis abyssinica), Digitta (Calpurnia aurea), Agam (Carissa Edulis), Dedeho (Euclea schimperi), Kinchibt (Euphorbia tirucali), Warka (Ficus vasta), Sholla (Ficus sur), Lenkuwata (Grewia erythraea), Kosso (Hagenia abyssinica), Tid (Juniperous procera), Attat (Maytenus arbutfolia), Indod (Phytolacca Dodecandra), Imbis (Rhus glutinosa), Kega (Rosa abyssinica), Injori (Rubus spp.), Kurkura (Zisphus abyssinica), Grawa (Vernonia amygdalina) and*

[2] A **wijjib** is a Holy worship and burial place, protected from human and livestock intervention and hence, densely covered with trees and other vegetations (Rahmato, 2001)

others such as Enbacho, Muwatis, Kulkual, to mention but a few. Most of these tree species are confined in Weyna dega and Dega agro ecology parts of the watershed.

While tree species such as *Eucalyptus globulus* have scattered in almost all parts of the watershed. Despite most of the woody vegetations are found on inaccessible areas such as hillsides and banks of the rivers, they have much potential for supplying fodder, poles, farm equipment, fuel wood, construction of fences and even houses.

Though natural woody plant covers are rare, there are shrub and bushes species include Erica arborea, Amijja and giant lobelia are dominantly occurred in patches in the highest elevation of the watershed. "Guassa" grass (*Festuca* spp.) is also common in these areas. The grass is important as a source of thatching material and serves as a livestock grazing site during seasonal droughts.

3.1.6. Social-Economic Characteristics

3.1.6.1. History

The watershed's history should be seen in light of the former Wollo province in general and its sub division werehimeno Awuraja in particular. Geographically, Wollo is the central locus of Ethiopia. By virtue of its geographical location, Wollo, both in the past and the contemporary history of Ethiopia, served as the melting pot for a number of Ethiopian nationalities

The watershed is occupied by a total human population size of approximately above thirty-five thousand, which makes a crude population density of of the watershed close to 146 persons per square kilometer, (Dega Zone being the most densely populated area) noticeably higher than the regional average of 113persons/km^2. The area is inhabited by Single ethnic groups mainly Amharic Speakers (Estimation from TWARDO, 2016).

Close to 95 % of the the communities were Muslim while nearly 5% follow Orthodox religion. Like many other parts of Wollo, the important element that makes the study area famous is its popularity in terms of mutual respect, tolerance and coexistence of Muslims and Christians, although the latter is small in numbers. It was based on this reality that Mesfin (1991) cited in Bantider (2007), wrote the following:

> *In Wollo, attitude towards religious differences are exceptionally good. They are characterized by mutual respect. Christians and Muslims live next to each other in perfect harmony and absolute peace. Even with in the same family half may be Christian and half Muslim. Moreover, there are some cases of intermarriage between religions, causing one of the partners to change religion.*

Even though the area has a long-recorded history of such fascinating and distinctive cultures, it is also memorized by the tragic images of death and destitution caused by recurrent drought induced famines.

Drought, recurring within intervals, has been features of the area since time immemorial contributing to prevalence of poverty in the area.

Men, women and children aged of seven (e.g. tending animals) and above participate in various activities to sustain households' livelihoods. Despite their roles vary considerably between and within the households, gender-based division of labor and disparity in decision-making power at the household level is still evident in the watershed. Women bear the burden of housework and care while men are mostly responsible for farming activities like land preparation, ploughing, planting /sowing, weeding, and harvesting. Women are also usually responsible for child care, water collection, food preparation, and firewood collection.

3.1.6.2 Household Size

As the field survey result reveals, the size of the household in the watershed ranged from single to eleven persons with an average of five members. This is higher than the average household size of Amhara regional state (4.6) and National average (5.1) (CSA, 2013). The largest proportions of the household (71%) have 4-5 members while those who have above 5 persons constitute only 3% of the population. If households' size is considered focusing on the economically active groups (conventionally defined age group classification, that is, members whose ages were between 15 and 65 on average), there were about 2.4 economically active populations per household (TWARDO, 2016).

Though there are some differences by households, the age distribution, generally shows high proportion of young population. The population size under the age of 15 years old constitute close to half of the total population (i.e. 47%). The overall dependency ratio of the households was found to be 96% which was composed of 92% young-age dependency ratio and 4 % old-age dependency ratio. However, almost every member of the household except the very young (<7 years) and the very old has to participate in some tasks, which are considered suitable for that particular member. For example, children with the age of seven and above contribute labor (at least rearing of livestock) (TWARDO, 2016).

3.1.6.3 Land Use and Farming System

According to Westphal (1975), there are four principal farming systems in Ethiopia, one of which is the 'seed farming complex' farming system of the northeastern highlands. The study watershed falls within this zone. As elsewhere in the highlands of Ethiopia, the population of the watershed is mainly engaged in crop production and animal husbandry that is carried on at subsistence level. Mixed crop-livestock system is the means of earning livelihood and income for the majority of people in the watershed. The existence of different agro-ecological zones favors cultivation of varieties of crops in the watershed. Rotating cereals with legumes was commonly practiced to improve soil fertility and crop yield (TWARDO, 2016). Almost all farmers of the watershed still practice conventional way of farming i.e. ploughing the land with oxen-drawn wooden ploughs with steel pikes or *ard* locally called *Maresha (*the tillage tool which was probably developed during the Axumite period (Nyssen et al., 2015). Ploughing using Hoarse/s is/are also common especially in the Wurch and high *Dega* agro ecological zones of the watershed. Before sowing repeated Plowing is common in the watershed since farmers believe that repeated Plowing controls weeds and improve cop yields.

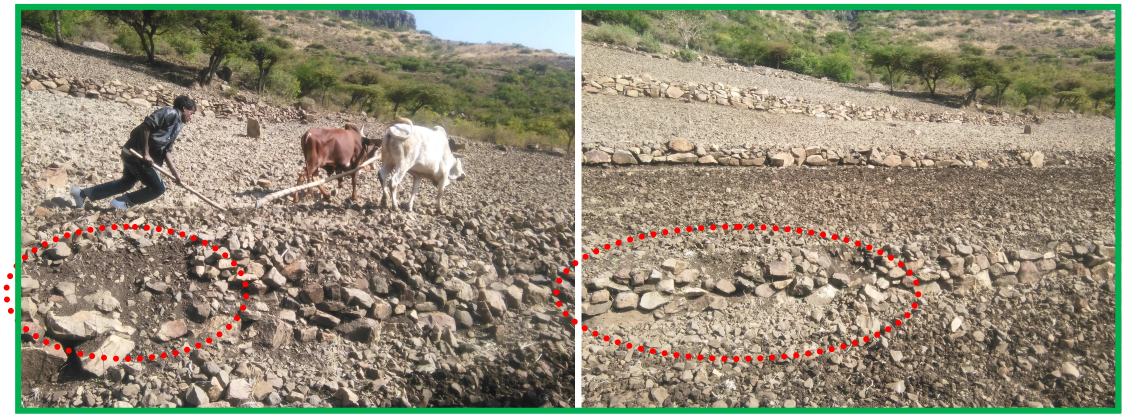

Figure 3. 8: Farmers Plowing **their land** (with oxen pulling) without maintaining SWC structures in Sengolla Kebele **(photo, Author, 2016)**

3.1.6.4 Land Holdings

Owing to the relatively high population size per unit area, rugged nature of the topography and land degradation, croplands in the study area has become more and more scarce. According to the survey data of sample kebeles within the watershed, there is a scarcity of land for crop cultivation and production of livestock in the watershed. In the absence of alternatives, an increasing number of farmers are cultivating hillsides and other marginal lands. The land holding of residents varies based on family size and perceived fertility status of the land. The size of land holding in the watershed ranges from less than 0.25 hectare to a high of 1.25 hectare, although those who hold the later are very small in number. The average size is 0.75 hectare per household (0.50 ha for croplands and 0.25 ha for grazing) which is less than an average cropland size of 1.2 ha and 0.98 ha per household respectively in the Ethiopian Highlands (CSA, 2007). The majority of households (91%) are concentrated in holding category of 0.25-0.75 hectare. 8% and 11% of the household hold less than 0.25 hectare and above 0.75 hectare respectively (TWARDO, 2016).

Land distribution was undertaken in the watershed 25 years ago (1991). During the distribution, an eligible age of individual to obtain land was 18 years and above. Otherwise, four childerns with age below 18 were considered as equivalent to an eligible individual and given a parcel of land which was comparable to the lands size of these individuals (18 years and plus). Hence, currently, there are a number of landsless youth who was either not eligible or not born during the distribution period. Many of them migrated to the urban areas. Those who are still there, either got small plots of land from family inheritance or waiting for a person to die or/and future land redistribution. In the absence of any alternatives, these landless rural youth also plow marginal lands as alternative income sources in order to survive.

The fragmentation of land holdings is serious problem in the watershed. Farmers hold plots which are fragmented and far apart. They operate at least two farmlands located at various distances from their homes. The time required to walk from a farmer's home to most distant plot averages 30 minutes. The distance varies in time from 5 to 90 minutes, with 72.5 percent of the plots being between five and thirty minutes away (TWARDO, 2016).

3.1.6.5 Crop Production

Crop cultivation is one of the most main components of rural livelihoods in the study area, which is mainly rained (Even though there is an insignificant proportion of irrigated fields) and subsistence type. The dependability, distribution and total amount of rainfall are key determinants of crop yield in the watershed. The crop production activities include plowing, sowing, weeding, harvesting and threshing. Weed control is the most labor demanding and time-consuming activity.

The precene of different agro-ecological zones enables cultivation of variety of crops in the watershed. However, crop diversity declines as one go from the Woinadega to Dega and Wurch parts of the watershed. The most important crops grown in the watershed include cereals (Barley (*Hordeum Vulgare*), Oats (*Avena Sativa*), Teff (*Eragrostis tef),* Wheat (*Triticum vulgare*), Emmer wheat (*Avena sativa), Sorghum (sorghum Bicolor); pulses* Horse Bean (Vicia faba), Peas (Pisum sativum), vetch (Vicia sativa), Chick peas (*Cicer arietinum),* Fenugreek (Trigonella Foenum –grecum*)* and lentil (Lens culinaris). Sorghum (*Hordeum Vulgare) and* Maiz (*Zea mays) produced on the lower reach of the watershed.* Vetch (Vicia sativa), Chick peas (*Cicer arietinum) are* grown when there is shortage of rain as they are drought resistant crops. In addition, some farmers produce oils seeds such as Niger seed (Guizotia Abyssinica*),* Rape seed (Brassica napus*),* lineseed (*Linum usitatissimum) and* spices and herbs (such as pepper, garlic, etc), and vegetables and root crops such as onion(Allium Cepa), tomato, carrot, cabbage, etc) on small scale using habitual systems of irrigation practices around homesteads. Moreover, some farmers produce spices, condiments (e.g. pepper), as well as aromatic and medicinal plants for local market and home consumptions.

Crops production is subsistence in nature and supplemented by livestock production. Frequent crop failure is common due to recurrent drought and long dry spells in the study area. In times of stress, some households supplement subsistence farming with cash income from seasonal labor, sale of small ruminants and cattle including the sale of firewood or charcoal as coping mechanisms. Off farm income generated from engaging in daily labor in the nearby urban areas, working on other farmer's farm, preparing local drinks, petty trading, weaving, smithing, carpentry and pottery practiced by small number of populations in the watershed but its share is insignificant.

3.1.6.6 Livestock Rearing and Management

Livestock production is crucial facet of the farming system in the watershed though number of livestock per household has generally declining with time basically due to lack/shortage of lands for grazing/browsing purpose. However, most of the households interviewed had still livestock of one sort or another.

The main livestock species in the watershed include cattle (*Bos indicus*), shoats such as sheep (*Ovis Aries*), goats (*Capra hircus*) and Equine such as donkey (*Equus asinus*) and horse (*Equus caballus*). Cattle constitute 63% of the total TLU followed by small equines which accounts for 19% of the total TLU. Furthermore, the number of livestock owned differs greatly between individuals. The coefficient of variation is generally high in equines particularly for mules and horses (Table 3.3). Livestock size is an important indicator of farmer's social status. A household head having a pair of oxen or above could be labeled as rich farmer.

Table 3. 3: Distribution of livestock sizes owned by the households

Livestock type	Total number	Mean/HH	Standard deviation	CV %	TLU[3]
Cattle (Oxen, Cows, Heifers & Calves	998	2.6	1.8	52	698.6
Shoats (Goats & Sheep)	1927	5.02	2.6	69	192.7
Donkeys	232	0.62	0.61	98	116
Mules	39	0.1	0.31	310	27
Horse	84	0.22	0.47	214	67

Source: Information Regarding the Livestock Numbers and Density (TWARDO, 2016)

Roles of livestock are manifold such as production of meat and milk for home consumption and market, supply of draught power, traction, manure, fuel in the form of dung cakes for household energy and transportation besides improving social bonding amongst the communities. Animal dung can also be sold to generate income with hard times. Pack animals provide rural transport. The donkeys are mainly used in transporting agricultural inputs and out puts. Cattle are generally the favored species among livestock in

[3] TLU- tropical livestock unit: (conversion factors; cattle=0.7, sheep/goat=0.1, donkey=0.5, mule= 0.7 and horse=0 .8, (Jahnke, 1982; EEA/ EEPRI, 2002)

the community. Although livestock are reared in all agro ecological zones, sheep and horses are more dominant in the *Dega* and *Wurch* zones, while goats are better accustomed to the relatively warm temperature environment in the lower reach of the watershed. Some farmers also practice backyard poultry at small scale because of increasing prices for egg and meat. Sales of livestock and livestock products cover partly or wholly the payments of taxes and other household expenses.

Crop-livestock interactions are strong in the watershed. Crop residues are commonly used as animal feed. After harvesting, stubble grazing on cropland is widespread. Livestock are given *Teff*, wheat and barley straw (locally termed as *Geleba)* and hay as supplementary feed, with oxen receiving special attention. Most grazing areas have been over exploited and forcing farmers to buy fodder (hay and straw).

There are various causative factors to the decline and/or shortage of feed supply for livestock. One of the reasons could be expansion of croplands into grazing lands. Moreover, poor soil fertility and rainfall variability and seasonal fluctuations drastically limit the quality and quantity of fodder available and crop residues obtained. Since grazing lands are shrinking, farmers use hillsides and other marginal lands for grazing purpose. The feed shortages and nutrient deficiencies are more severe in dry seasons.

3.1.6.7 Housing quality

Housing quality tend to vary more across rural areas. Farm implements are important assets in the rural households. The majority of households live in single-room houses. The majority of households do not have separate kitchen room for cooking. Wood, stone and mud are the most common construction materials of wall of houses. Mud or dung is the most common flooring materials in most housholds. The roofs are mixed, however, predominantly made of thatch and corrugated iron sheets. All most all of the households' fetch drinking water from rivers, wells, springs, ponds, though communal tap are found in some places.

3.1.6.8 Food security

As already noted above, the economy of the inhabitants in the watershed is predominantly based on traditional plough agriculture. Since the agricultural activities are constrained by various interrelated natural and human induced factors, the watershed in particular and the district (in which the watershed is found) in general has been registered as the food insecure areas in the ANRS. As in most other drought affected areas of the country, food security in this watershed is precarious, among others, due to a high density of population, small size of land holdings per household, heavily reliance on rained agriculture, soil erosion problem and decreasing inherent soil fertility. Hence, the study area for many decades depends on external food aid to fill the food deficits (TWARDO, 2016).

3.2 Research Philosophy, Methodology and Approaches

This section describes the philosophical belief underpinning the study, the methodological approach and research design adopted, the data types used and the research approaches and strategies which guided the data collection and analysis processes.

3.2.1 Research Philosophical Foundation

There are various paradigmatic bodies of literature and theoretical assumptions governing geographical researchers. These assumptions could be either ontological which is related to the perception of reality of nature (Denzin, 2010) and/or epistemological which related to nature of production and dissemination of knowledge (Cohen et al., 2002).

Creswell (2009) identifies four philosophical paradigms (common set of philosophical beliefs); namely, post-positivism, constructivism, participatory, and pragmatism. This research is supposed to be ascribed to all of these paradigms. Since this research applies experiment and survey strategies in an attempt to collect statistical data using predetermined instruments, it falls under post-positivism paradigm. Since this research tries to integrate the rural communities' experiences of their environment; attach meaning to their feelings, perception and their trajectory, it favors constructivism/interpretivist paradigm. In view of the fact that this research applies to mixed approach (i.e. depend on both quantitative and qualitative data) to best understand of the research problem, it falls to Pragmatism paradigm.

3.2.2 Methodological Approach

This study emphasises on the fact that the contemporary human-environmnet relations and environmental studies requires a holistic approach of integrating the biophysical, socio-cultural, economic and institutional data, techniques, tools, perspectives and concepts in natural resource management. Cohen et al (2002) suggests that the choice of research methods should be drived by the nature of research questions. Since, a single research method can not adress all dimensions of a complex research problems, this research applies holistic and interdisciplinary approach, by integrating use of a range of natural and social science methodologies. This is based on the premise that mixing methods enable to bring together the strengths of various methods within the same research problems and environmental issues. The mixed research approach was customized to fit the research objectives. Qualitative approaches employed to explore perceptions of the local communities on land degradation problems and SLM practices at both the household and community level from people's perspectives. This belief supports Dahlgren et al (2007) arguments that qualitative methods are ideal participatory approaches to investigate perceptions and provide a greater depth of information on the reality of the situation from the perspective of target population in a context-specific setting.

3.2.3 Research Design

Research design explains the framework of the research. In this study, a combination of *ex-post (for analysis* of intervention programs) and place-based case study research design are preferred and adopted. As Yin (1994, 2009)) explains, a case study is a pragmatic investigation of contemporary phenomenon "*within its real-life context*" based on several data collected from multiple sources, as envisaged by the mixed-methods approach. Moreover, it is the author's conviction that case studies are able to provide explanatory insight into the society-environment nexus research problems that large-scale studies overlook (Yin, 2009). Kerlinger and Rint (1986) explained that the ex post facto research design is ideal for establishing the possible relationship among the variables by observing the present condition and looking back for some possible contributory factors. For this research, this design is found to be appropriate as the sustainable land management program particularly soil and water conservation has long history in the area.

3.2.4 Data Types, Sources and Methods of Data Collection

SLM is a complex process that involves multi levels and multi stakeholder's approaches that needs integrated and multi-resource management planning process to balance ecological, economic, and cultural/social objectives of the area concerned. Based on these grounds various types of data (biophysical and socioeconomic data) were gathered from both primary and secondary data sources through multiple methods of data collection techniques. In this line, Neumann, (2009) explained that since the human-environment interactions are complex it needs consideration of geographical and socioeconomic data gathered through a variety of data collection methods. The following specific data gathering procedures were deemed credible for this study:

3.2.5 Biophysical Data collection and Analysis Methods

3.2.5.1 LULC change detection and analysis

3.2.5.1.1 Remotely Sensed Data Type and Sources

Though remotely sensed data are vital in LULC change studies, it cannot provide complete answers for the questions like why and how changes are occurring (Fisher, 2012; Sohl and Sleeter, 2012). Hence, to fully address the complex trends of LULC dynamics and describe the underlying drivers behind across spatial and temporal scales, it is mandatory to incorporate other biophysical and socio-economic data (Turner et al. 1995; Lambin et al., 2003).

This study employed a combination of techniques to evaluate LULC dynamics, the major drivers and implications behind them. First, the trend and level of LULC change over the last four decades was analyzed using satellite image and GIS techniques complemented with field observations (particularly for the current status). Second, socioeconomic surveys were undertaken to examine local perceptions related to LULC changes and the drivers behind. Third, the overall implications of such changes on biophysical environmnets and local livelihoods of the watershed were referred and linked from existing literatures.

Four sets of digital satellite imageries such as Landsat MSS, TM, ETM+, and Landsat 8 of the year 1973, 1986, 2001 & 2017, respectively were used to examine LULC dynamics over a given period in the watershed. The selection of these satellite images was entirely based on the quality (e.g. cloud free) and long time series availability, correspondence with years of major regime/policy changes and/or events in the country, purpose of the question to be answered, and suitability of the seasons for collecting socioeconomic field data. The Landsat MSS 1973 image had a resolution of 79 meters; while the Landsat TM 1986, Landsat ETM+ 2001 and landsat 8 images have a resolution of 30 meters (Table 3.4 & Fig.3.9). All these terrain-corrected and radiometrically calibrated Landsat images were freely accessed and downloaded from the online archive of the United State Geological Survey (USGS) Centre for Earth Resources Observation Systems (EROS) available at (http://earthexplorer.usgs.gov/). It would have been better to start with medium resolution images such as Landsat TM images for the study but since there were no such images in the 1970s; a lower resolution Landsat MSS 1973 image was taken as reference year for this study. During the acquisition of satellite image and associated metadata, information pertaining to platform, sensor calibration, projection, coverage, resolution, cloud covers and other relevant information were taken in to account. The effects of solar illumination angle induced by the rugged terrain nature of watershed which may cause different reflectance for the same cover type were considered.

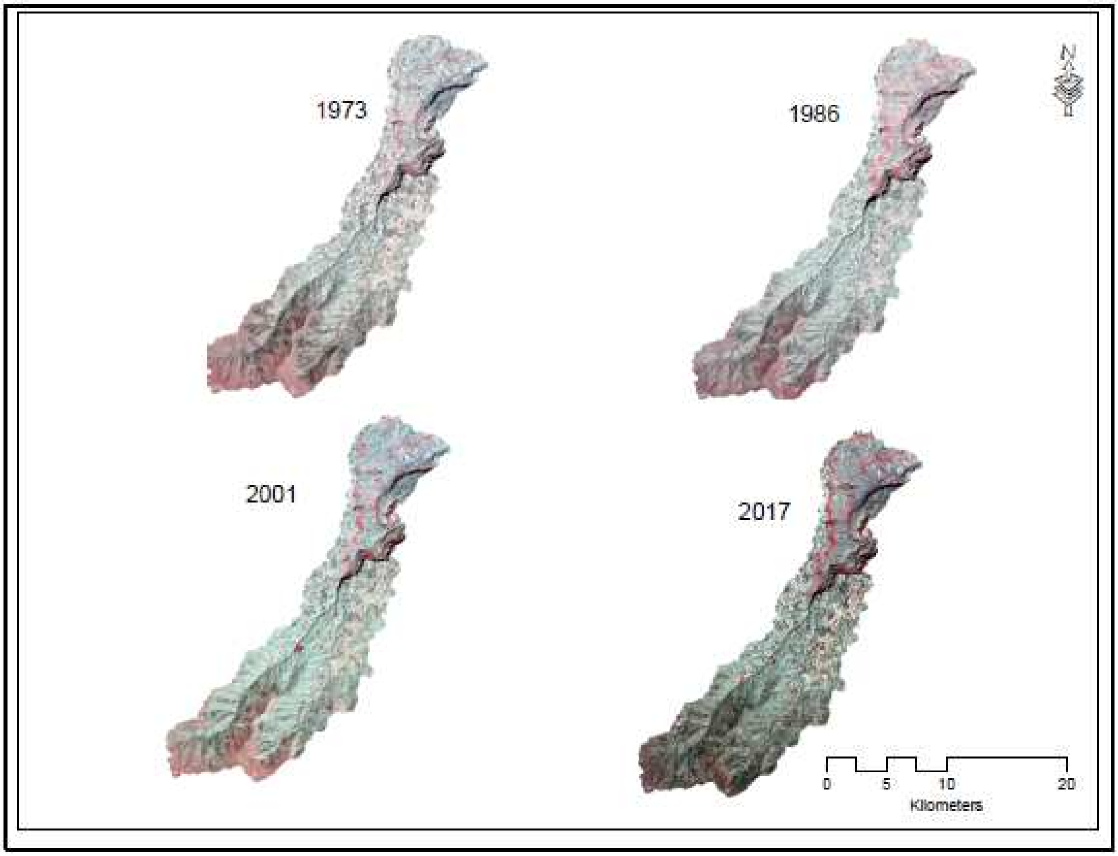

Figure 3. 9: **Land sat images used for LULC classification and Analysis**

The acquisition dates of images were made as close each other as possible to minimize troubles related to seasonal variations. Moreover, dry and clear sky months (December to January) were preferred to mitigate the effects of atmospheric conditions that blight the quality of optical remote sensing imagery. Since these months are seasons of harvesting, they are relatively ideal to easily identify each land use/cover types.

All imageries were projected to UTM zone 37 N using WGS datum (WGS_1984_UTM_Zone_37N) to ensure uniformity between datasets during analysis. Data sets, sources, and specifications used for the study are displayed in the table below.

Table 3. 4: Landsat scenes, source and specifications used for the study

Characteristic	Landsat MSS	Landsat TM	Landsat ETM$^+$ SLC-on	Landsat 8 OLl/TlRS
Data Set Attribute	MSS L1G	L5	L7	L8
WRS Path/Raw	181/052	168/052	168/052	168/052
Number of Bands	4	7	8	11
Pixel resolution	79 × 79m	30m x 30m	30m x 30m	30m x 30m
Acquisition Date	31-Jan-73	23-Dec-86	22-Jan-01	10-Jan-17
Sources	EROS/ USGS	EROS/ USGS	EROS/ USGS	EROS/ USGS
TM = Thematic Mapper; ETM+ = Enhanced Thematic Mapper Plus; OLI = Operational Land Imager, TIRS = Thermal Infrared Sensor				

3.2.5.1.2 Supplementary *Data*

To validate classified images accuracy and further investigate driving forces and associated impacts of LULC changes, supplementary data, such as DEM, topographical maps and socio-economic data were collected from various sources. The Shuttle Radar Topography Mission (SRTM) DEM (30 m spatial resolution) was obtained from the USGS (https://earthexplorer.usgs.gov/). A digital elevation model was used for extracting slope properties, prepare topographic map, delineate and identify sub watershed areas, among others. The high-spatial resolution Google Earth was employed to collect the training and testing samples points for LULC classification and validation. The 1993 edition three sheets of (1039 A1, 1139 C3 & 1139C4) 1:50 000 scale and 40 m contour interval digital Topographic map were purchased from EMA and used for geo-referencing of satellite images, preparation of the base maps and for LULC class verification and interpretation.

Socio-economic data were collected from the community through a series of questionnaire, key informant interview, focus group discussions which was facilitated by local development agents with the presence of the author and complemented by onsite field observations. The data type captured from local knowledge were the nature of LULC change over time, perceived drivers of such changes and site-specific management efforts. Additional information supporting the interpretations, including policy documents, proclamations, implementation guidelines and statistical reports were obtained from national and regional government's offices and official websites. Data analysis was done using SPSS v 22 and MS Excel 2010 Packages while the Satellite image analysis was performed with the help of ArcGIS 10.3 and ERDAS IMAGINE 2014 Software.

3.2.5.1.3 Data Verification and Error Control

Data verification and error control have been given special attention in this study. To identify and interpret the main LULC types, field visit and observations was carried out at different times in the watershed. During the field survey, data on the historical and present LULC types were collected and localized by using GPS (GPS- GARMIN-60). Moreover, these reference areas were documented by photographic images to strengthen the reliability of the data gathered. The GCPs information for the LULC types of the past were identified from elderly people, author's prior knowledge and knowledgeable assistants from related government departments, such as agriculture and Natural resource offices of Tenta *Woreda*.

3.2.5.1.4 Digital Image Processing and land use/cover mapping

After selection and acquisition of appropriate satellite imagery in terms of coverage, resolution and accompanying metadata from the sources, an intensive preprocessing, such as re-sampling and layer stacking of the required bands; atmospheric, radiometric and geometric corrections; and temporal as well as topographic normalizations of each satellite image were performed. To ensure image pixels uniformity, Landsat MSS 1973 image was re-sampled to 30 m pixels using the nearest neighborhood method (Johnson, 2015). Then, the study area was extracted from the images using subset tools in Erdas Imagine 2014. After creating subset images covering the watershed and checking the quality of the image, a classification scheme was developed to derive various LULC classes of the watershed.

To classify LULC categories, more than three hundred randomly distributed training sets of data, varying in size from 20-60 based on area coverage, were employed to locate training pixels for each LULC category and study periods. The training sites for recent images were generated by GPS reading supported by high resolution Google earth images while the training sites for older historical images were assigned with the aid of raw images visual interpretation, topographic maps, old black and white ground photographs of some sites within the study area, supplemented by local elder's information and author's prior knowledge. This approach was used by other researchers in their study of LULC change in Ethiopian highlands (Kindu et al., 2015, Demissie, 2017). The training signatures were then evaluated for class separability between LULC classes. In the evaluation stage, signature editions were done by deleting, merging or renaming until the desired result was achieved.

Finally, supervised classification and visual interpretation technique were applied for all the images, following Maximum Likelihood classification algorithm and change detection comparison strategies. In the process of classifications, some land use/cover units were misclassified to other classes. For instance, bare lands were misclassified to the farmland/settlements class. This happens due to the fact that some bare land's spectral properties appeared similar to that of harvested croplands which bring difficulties in distinguishing them during image acquisition. To improve classification accuracy and reduce misclassifications, recoding techniques were applied to clean misclassified ones using ERDAS software through visual inspections.

To simplify and reduce the number of LULC classes, some related LULC classes were merged together into one class. For instance, Croplands and settlements were aggregated as farmlands/ Settlements as it was difficult to identify the scattered nature of the rural settlements, where in many cases hamlets are surrounded by farmlands, into separate land use/cover types. Similarly, due to the intermingled nature of shrub and bush lands, it was difficult to distinguish these two categories and hence was labeled as shrub/bush lands to report the LULC study results (Table 3.5). Nonetheless, the authors realized that combining the different LULC classes could hidden differences among them and may exert its impact on the quality of the outputs (Misana et al., 2012). The LULC classification was adopted and modified from FAO LULC classification scheme, which is widely applicable in most of developing countries. for ease comparison of results, LULC nomenclature and descriptions commonly used for Ethiopia were refered and adopted.

Table 3. 5: **Description of LULC Classes in Gedalas Watershed**

S/N	Land Use/ Cover Classes*	Description
1	Woodlands/plantations 	Areas covered with intricate mixture of small trees and bushes. These categories also incorporate *Eucalyptus* woodlots and/or other remnant woody plantations found mainly in the form of farm boundary, in and around scared sites.
2	Shrub/Bush lands 	Areas covered with woody shrubs, thorny bushes and scattered or patches of various species of small trees, usually found along banks of streams, rugged landscapes and escarpments. Some of these land cover is used for communal grazing and browsing purpose. Some Enclosures are included in this category
3	Grasslands  	Land units (privately and communally owned) covered by pure stands of grass and/or forbs used for hay making and grazing and browsing areas for livestock
4	Farmlands/ Settlements 	This categories include areas used for crop cultivation (either on a rain-fed basis or using irrigation); areas covered by rural towns, scattered hamlet, backyards, churches, schools and mosques and other institutions spatially mixed in a fuzzy manner.
5	Stream course/ beds 	Land covered by major intermittent streams and boulders found on the beds and along the banks of streams
6	Bare lands 	Areas with little or no vegetation cover consisting of barren eroded landscapes and/or exposed rocks.
7	Afro/Sub afro alpine vegetation 	Areas covered by herbaceous vegetation-type including shrubby herbs and tussock-forming grasses grown at highest altitudes of the watershed.

* Since the LULC natures of the watershed are mixed each other in an intricate manner, it was very difficult to make further distinction; hence, generalized information is presented above.

3.2.5.1.5 Post classification Accuracy Assessment

In order to evaluate classification accuracy, more than 300 validation points, which were spatially and temporally distributed in the whole watershed and categorically encompassing all LULC types were generated through stratified random sample strategy (Jensen, 2015).

Corresponding high resolution Google Earth images were used as additional sources of information that aided the validation process. However, for the year 1973, quantitative accuracy assessment were not done due to absence of validated map, high resolution Google Earth images and aerial photographs of the watershed for this particular year. Therefore, to ascertain the relative classification accuracy of this year, invariant ground features were employed as validation data and a qualitative comparison of the classified map were compared with these ground features (Sabr et al., 2016). Finally, the poster size colour printout hard copy of the classified map unit of 2017 was taken into the field to check the reality on the ground cover classes and to improve the classification accuracy.

Then, the overall accuracy, Kappa coefficient, producer's accuracy and user's accuracy were calculated from the error matrix (Foody, 2002; Fan et al, 2007; Congalton and Green, 2009). The overall classification accuracy was computed by dividing the number of correct values in the diagonals of the matrix to total number of values taken as a reference point; producer's accuracy was derived by dividing the number of correct pixels in one class divided by the total number of pixels as derived from reference data; user's accuracy was calculated by dividing correct classified pixels by the total number of pixels and Kappa coefficient, which indicates the agreement between the classification map and the reference data, were calculated as per Bishop and Fienberg, 2007(eq.3.1);

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+})(x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+})(x_{+i})} \qquad (3.1)$$

Where, *K* is Kappa coefficient, *r* is the number of rows in the matrix, *xii* is the number of observations in row *i* and column i (the diagonal elements), *xi*+ are the marginal totals of row *i*, *x* + *i* are the marginal totals column *i*, and *N* is the total number of observations.

3.2.5.1.6 Change detection & Analysis

The changes in LULC that had occurred in the watershed over the period of study were detected through post-classification comparison approach (Singh 1989; Fan *et al.*, 2007, Chen *et al.,* 2012*).* Post classification comparison (map-to-map comparison) methods were preferred in this study for the number of reasons. Firstly, this method enables to compare multi-temporal images recorded by different sensors under different environmental and atmospheric conditions (Singh, 1989; Yuan et al. 2005). Secondly, these methods provide the extent and nature of 'from-to' change information (Jensen, 2015). Based on this ground, four LULC maps were compiled to display the type of LULC classes and compare between the classified images. Then the whole study period (1973-2017) was classified into four sub-periods (1973 to 1986; 1986 to 2001; 2001 to 2017; and 1973-2017 which includes the entire 43 years of study periods). Then, paired overlay was performed through spatial analysis in GIS in order to detect, compare, and analyze patterns and directions of changes and to quantify persistence, gains, losses, total change, net change, and swapping of LULC occurred during the time period considered in the watershed (Pontius et al., 2004).

The percentage share of each LULC type in a study area was computed as (eq. 3.2):

$$Z = \frac{xi}{Y} * 100 \qquad (3.2)$$

Where Z is percentage share of each LULC type, xi is area of each LULC type, and Y is the total area of the study area.

To determine the magnitude, trend and rate of LULC changes in the watershed, the area comparison analysis was made by subtracting the total area of each classes of 1973 from 1986, 1986 from 2001, 2001 from 2017 and 1973 from 2017 which the result could be positive (increasing) or negative (decreasing). The percent and rate of LULC change were computed by the following formula (Kindu et al., 2015; Demissie et al., 2017):

$$\boxed{\text{Percent of change} = \frac{A-B}{\text{B}} * 100} \tag{3.3}$$

$$\boxed{\text{Rate of change (ha/year)} = \frac{A-B}{\text{C}}} \tag{3.4}$$

Where, A is area of LULC (ha) in time 2, *B* is area of LULC (ha) in time 1; *C* is Time interval between *A* and B in years.

Conversion matrix was used to distinguish the changes of each category at the expense of others and its general structure is indicated on Table 3.6. The rows and columns in the table display the categories of time 1 (initial Time), and time 2 (subsequent time), respectively. on The diagonal entries (that is, Pjj) portray the amount of LULC category which remained persistence of class j between the time period and used to calculate the gains and the losses of LULC classes while the off-diagonal entries show the size of the area that transitioned from category "*i*" to a different category "*j*" during the time interval (Aldwaik and Pontius, 2012). For ease of reference, the equations and notation used to compute various components are presented as follows:

The area of the watershed Pi+ that is covered/used by class i in Time1, is given by (Eq 3.5):

$$\text{pi+} = \sum_{i=1}^{n} \text{pij} \tag{3.5}$$

Where n is the total number of LULC classes. Similarly, the area of the watershed P+j that is covered/used by class j in time 2 is given by (Eq 3.6):

$$\text{p} + \text{j} = \sum_{j=1}^{n} \text{pij} \tag{3.6}$$

Table 3. 6: A 7 x 7 LULC Transition matrix

Time 1	Time 2							Total Time 1	Loss
	LULC 1	LULC 2	LULC 3	LULC 4	LULC 5	LULC 6	LULC 7		
LULC 1	*P11*	*P12*	*P13*	*P14*	*P15*	*P16*	*P17*	*P1+*	*P1+- P11*
LULC 2	*P21*	*P22*	*P23*	*P24*	*P25*	*P26*	*P27*	*P2+*	*P2+- P22*
LULC 3	*P31*	*P32*	*P33*	*P34*	*P35*	*P36*	*P37*	*P3+*	*P3+- P33*
LULC 4	*P41*	*P42*	*P43*	*P44*	*P45*	*P46*	*P47*	*P4+*	*P4+- P44*
LULC 5	*P51*	*P52*	*P53*	*P54*	*P55*	*P56*	*P57*	*P5+*	*P5+- P55*
LULC6	*P61*	*P62*	*P63*	*P64*	*P65*	*P66*	*P67*	*P6+*	*P6+- P66*
LULC 7	*P71*	*P72*	*P73*	*P74*	*P75*	*P76*	*P77*	*P7+*	*P7+- P77*
Total Time2	*P+1*	*P+2*	*P+3*	*P+4*	*P+5*	*P+6*	*P+7*	1	
Gain	*P+1 – P11*	*P+2 – P22*	*P+3 – P33*	*P+4 – P44*	*P+5-P55*	*P+6-P66*	*P+7-p77*		
Note: "P" refers to any conversion from one land use /cover (LULC) to another & the number refers to Columns & rows of LULC categories									

Source: Modified from Pontius et al., (2004); Braimoh, (2006); Bantider, (2007); Adugna et al. (2017).

Similarly, the gain, loss, persistence, swap and total change were calculated for all the four-classified imagery. The Gain was computed by subtracting the difference between the total value for time 2 and the persistence. On the other hand, the Loss was the difference between the total values for the time 1 file and the persistence. The swapping is the exchange between the categories i.e. the proportion of a given class that changes location, while the total surface area remains the same. It denotes concurrent gain and loss of a given LULC class.

Swap indicates the fact that a lack of net change does not necessarily mean a lack of change in LULC in the watershed. It was calculated as two times the minimum value of the gains and losses. The net change indicates the definite change between two periods of time. It was determined by calculating the difference between the Total column and the Total row. The total change for each category was the sum of net change and the swapping, or the sum of gain and loss. If the net change is zero (implying gain is equal to loss), then the swap is twice the loss or gain (Pontius et al., 2004; Braimoh, 2006).

The exposure of each LULC classes for a change were assessed using the loss to persistence ratio (Lp= loss / persistence) which assesses the vulnerability of a LULC classes for a change; gain to persistence ratio (Gp = gain/ persistence) which evaluates the gain of a land use/cover in comparison to its time 1 size, net change to persistence ratio (Np = net change / persistence) (Braimoh, 2006; Ouedraogo *et al.,* 2010).

Values of *Gp* and *Lp* greater than one imply that a given land use/cover class has a higher probability to change to other LULC class than to persist in its current condition (Braimoh, 2006). If the value of *Np* was negative, the LULC class would have a higher probability to lose area to other LULC classes than to gain from them.

Finally, two sorts of data were generated; namely, four LULC maps (Fig 4.1) which illustrates the changes in a spatial context and various tables which exhibit the amount of areas for each LULC categories (Table 4.2) and a cross-tabulation matrix which demonstrate LULC transition from category to category at different study periods (Table 4.3). Moreover, bar graphs and tables were used to display quantitative LULC class I relation to topography (i.e. altitude, and slope categories).

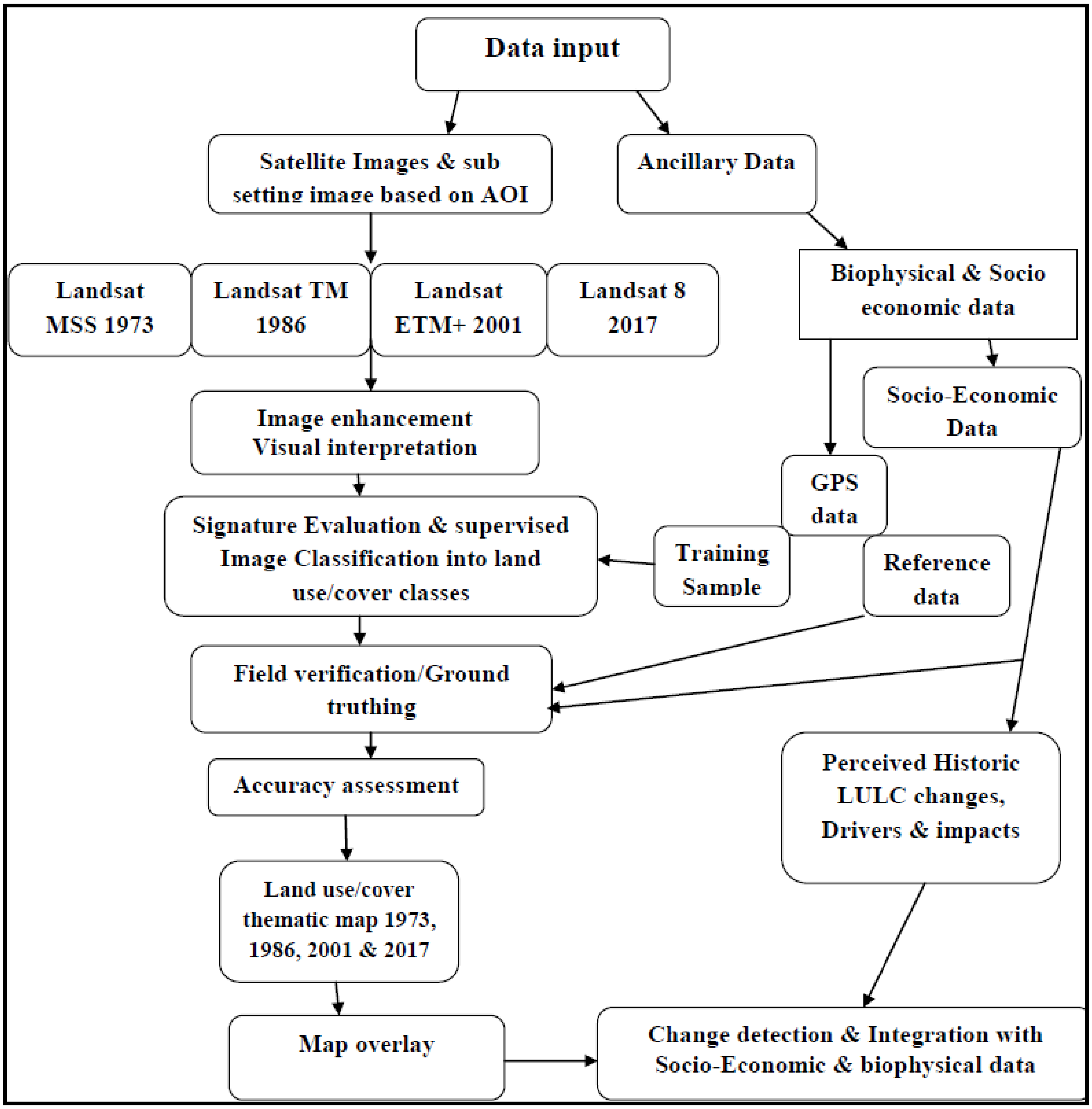

Figure 3. 10: Methodological flow of land use/cover analysis (Source: Own drawing, 2017)

3.2.5.2 Method for Soil Erosion assessment and Analysis

3.2.5.2.1 Data Type and Sources

The soil erosion process is a complicated system controlled by a multitude of factors comprising soil characteristics, local climatic conditions, nature of terrain features, ground cover, land use types, conservation practices, and interaction among them. Hence, both quantitative and qualitative methods were employed to take advantage of their complementarities and counterbalance inevitable weaknesses of each approach. With the aim of triangulation, digital and non-digital data were collected from many sources including field inspection. Most input factor of RUSLE model was estimated using selected methodologies or obtained from literature that have been developed specifically for Ethiopian context. For each factor considered in the RUSLE model, a respective file was built in the GIS environment and finally merged together in the model to generate final map that indicates soil loss rate of the watershed. The data inputs pertaining perception and experiences of local communities were collected through one-on-one scheduled interviews with sample household's heads, focus group discussions, in-depth key informant interview, and observations of plots and its environs with sample household heads.

Table 3. 7: Data type, Source and description used in the study

Type of input Data	Data Sources	Description	Purpose of the data
ASTER Digital Elevation Model (ASTER DEM)	USGS/EROS) http://gdex.cr.usgs.gov/gdex/	30 m Resolution	For land use/cover classification of the watershed
Landsat 8 Satellite Image	USGS/EROS) http://earthexplorer.usgs.gov/	30 m Resolution	
Soil Data	MoWR of Ethiopia	The digital soil map prepared by the Ethiopian MoWR based on FAO–UNESCO– ISRIC soil classification system	To assess soil erosion magnitude of the watershed
Rainfall Data	Ethiopian Meteorological Agency	Station and Grid Rainfall Data for a period of 31 years	To identify Rainfall and temperature trend of the watershed & to use Rainfall information as in input data for soil erosion assessment
Land Management/ Conservation Support	Household level survey, key informant interviews Field observation, Google earth images, SAS planet and Literature review	Data on the state of the watershed such as kind of support practice, land use/cover, conservation strategies etc.	To assess the existing state and prospects of SLM in the watershed

Source: Compiled by the Author, 2017

3.2.5.2.2 Soil Erosion Models

Though soil erosion menace and associated land degradation and sedimentation persist throughout the geologic time scales, the circumstance is bothered in recent times with man's expanding mediations with the natural environment. Thus, estimation of soil erosion has become a basic issue and remains being one of the real research topics at various spatial and temporal scales using proper model (Ganasri and Ramesh, 2016).

There are a wide variety of models used to estimate soil erosion over many years worldwide (Lal, 2001; Morgan, 2009; Farhan and Nawaiseh, 2015). These models can be physical-based, empirical, and conceptual (Brady and Weil 2002; Farhan and Nawaiseh, 2015). The choice to apply these models depends on the availability of input data and type of information needed. With these in mind, The RUSLE model, which is the most widely applied empirical model, was adopted for this study. The essential supposition in the RUSLE model is that detachment and deposition are governed by the sediment load of the runoff. Soil erosion is limited by the transporting capacity of the flow instead of lack of materials eroded from the sources. If the sediment load of runoff exceeds the transporting capacity of the flow, soil detachment can no longer take place (Ganasri and Ramesh, 2016).

There have been a number of studies published that apply RUSLE model to estimate and predict soil loss rate worldwide (Prasannakumar et al., 2012; Farhan et al., 2013; Ganasri and Ramesh, 2016). This model, coupled with GIS and RS, has also been widely applied and tested by many researchers to estimate soil erosion potentials in the highlands of Ethiopian (e.g. Meshesha et al., 2012; Haregeweyn et al., 2013; Gelagay and Minale, 2016; Fenta et al., 2016; Woldemariam et al., 2018; Haregeweyn et al., 2017). These studies supported the existing literature that indicates the efficacy of RUSLE model to adequately estimate soil loss rate in a wide range of environments.

However, the model only addresses rill and inter-rill erosion induced by the impacts of raindrops and surface runoff without accounting for other forms of erosion such as gully development and sliding of lands (Renard et al., 1997). Moreover, RUSLE model has the tendency to overestimate soil loss for a higher range of slopes and heterogeneous landscapes (Renard et al., 1991).

Nevertheless, due to complete absence of the required data (e.g. Sediment deposition and shorter interval rainfall intensity data), to select other data intensive models, RUSLE model was still adopted to be applied for investigating the amount of mean annual soil loss within the study watershed. Some of the reasons for the selection the model includes its less data requirements, free and readily availability of the required of data sets; its relative simplicity to apply and its compatibility with remote sensing and GIS inputs in computer interface (Farhan and Nawaiseh, 2015). Moreover, most of the input parameters of the model are calibrated for the Ethiopian context (Hurni, 1985). Most importantly, although many researchers employed RUSLE models to assess rate and patterns of soil loss in other parts of the Ethiopian highlands (e.g. Tamene et al., 2017); this model was probably used for the first time to assess soil loss rate in a GIS framework in the Gedalas watershed of the Beshillo Catchment.

3.2.5.2.2 RUSLE Model Structure and Parameters Description

To estimate annual mean soil erosion caused by rainfall, and identify the spatial pattern of the potential soil loss risks in the watershed, RUSLE model erosion input factors were structured in raster format of five multiplicative equation (eq. 3.7) (Renard et al., 1997) and given as follows:

$$A = R * K * LS * C * P \tag{3.7}$$

Where A = Average annual soil loss per unit of area (ton ha^{-1} yr^{-1}); R = the rainfall erosivity factor [MJ mm, (ha^{-1} h^{-1} $year^{-1}$)]; derived from daily precipitation data; K = the soil erodibility factor [ton ha^{-1} h MJ^{-1} ha^{-1} mm^{-1})]; derived from information on soil types; LS = topographic factor, i.e., length of the slope and percent of the slope steepness (dimensionless), respectively; derived from a DEM; C = the land cover and management factor (dimensionless); derived from LULC classification of satellite image data; and P = the conservation support factor, which accounts for soil erosion control measures (dimensionless) derived from field observation and literature.

Rainfall erosivity factor (R)

Rainfall erosivity (R) is the power of rain to induce soil erosion. In this study, it represents the power of an average annual value of precipitation to cause soil erosion (Lal, 1990; Farhan and Nawaiseh, 2015, Tamene et al., 2017). The R factor is a complex process potentially affected by the amount, duration, intensity, energy and size of rain drops and pattern of rainfall and rate of the resulting runoff (Farhan and Nawaiseh, 2015). This factor is considered as the most influential for soil erosion in different studies (Wischmeier and Smith 1978). Rainfall erosivity can be derived from rainfall intensity for the particular period of the area considered (Kouli et al., 2009; Renard et al., 1997). However, such data are not readily available at many meteorological stations, including the study area, due to absence of automatic rain gauges. For this reason, R factor was estimated from the long-term mean annual precipitation values of the watershed (Renard et al., 1997).

In this study, the rainfall erosivity factor of the watershed was generated based on both observed average annual precipitation (mm) data (Converted from daily average) recorded by *Amba Mariam* rainfall station and gridded rainfall data. As noted by Panagos et al. (2015), since annual rainfall erosivity significantly fluctuates, at least 15 years of data are mandatory to attain representative estimates of rainfall erosivity. Moreover, the altitude of the watershed extends from 1919 to 4233 m a.s.l. This may cause variations in spatial and temporal distributions of the prevailing rainfall in the watershed. With this in mind, and to adequately represent rainfall characteristics of the entire watershed, more than 30 years of 10 sites (from within and around the watershed) reconstructed gridded rainfall data series were used in conjunction with rainfall data from *Amba Mariam* meteorological station. Similar approaches were employed by Asfaw et al., (2018). The reconstructed gridded data with spatial resolution of 10×10 km and temporal resolution of ten days were obtained from NMA of Ethiopian. Since gauge weather stations are limited in number and distribution, the reconstructed gridded data were used for this study. As noted by Mengistu et al. (2013), there is a strong association (r =0.8) between the station based observed and reconstructed gridded data. Hence, filling the gap with reconstructed data for this study where there is a paucity of meteorological stations is reasonably appropriate.

The daily rainfall data from the identified grid sites and the *Amba Mariam* station was first summed to get annual rainfall amounts and annual mean rainfall was generated for each station for the years considered. Then, the R factor value was calculated following the readily available regression equation developed by Hurni (1985) to estimate rainfall erosivity for the Ethiopian highlands (Equation 3.8)

$$R= -8.12+ (0.562*P) \quad (3.8)$$

Where, R refers *to* the rainfall erosivity factor while P denotes to the mean annual Precipitation (mm).

Finally, the annual rainfall amounts were spatially interpolated using an inverse distance weighting (IDW) interpolation techniques and erosivity raster map was prepared for the whole watershed with the aid of ArcGIS 10.3 software. IDW interpolation techniques has been preferred as geo-statistical spatial interpolation methods because it is easy to generate relatively accurate rainfall erosivity information from known sample points to the points of unknown values at a closer distance than those located far. Moreover, it is favored with the assumption that it enables quick interpolation of the required data from grid based irregularly spaced samples (Li and Heap, 2008). The R value ranged from 513 to 519 MJ mm/ha h yr A similar approach was adopted to compute the R factor in Ethiopia (Bewket and Teferi, 2009; Abate, 2011). Fig. 3.11 **s**hows the rainfall erosivity values and spatial distributions across the watershed.

Soil erodibility Factor (K)

Soil erodibility is the inherent aspect of soil properties reflecting the vulnerability of a soil to erode, as influenced by the biophysical and chemical characteristics of the soil (Renard et al., 1997; Farhan and Nawaiseh, 2015; Panagos et al., 2015; Fenta et al., 2016).There are different approaches developed by scholars to determine soil erodibility factors (Romkens et al., 1997). However, the type of data available in the study area governs the choice of the approaches. Due to paucity of data, only soil colors and stone covers were selected to determine K factor values for this study as recommended by Hurni (1985) for Ethiopian conditions. The soil units map of the watershed was extract from the digital soil map of the master plan of Blue Nile basin which was prepared by the then MoWR of Ethiopia (MoWR, 1998). Then, four dominant soil units; namely, Leptosols, Regosols, Cambisols and Vertisols were identified (Fig. 8) and delineated on the map of the watershed using ArcGIS 10.3 “Spatial Analyst” Geo processing tool. To validate the value of the K-factor, actual observation and field-based soil sample color estimation was carried out using a Munsell color chart.

Since stone covers reduce soil erodibility by a certain percent (Panagos et al., 2015), the role of stone cover on the K-factor was incorporated in the K factor estimation. As observed from field survey and the author's knowledge of the area, most surfaces of soil units of the watershed are interspersed with stone contents which are protection against soil erosion by water (Poesen et al., 1994). Accordingly, 40%, abundant of surface rock fragments and corresponding 0.80 erodibility values was assumed for all soil units (Fenta et al., 2016). Estimation of surface rock fragments of each soil unit was conducted during a transect walk based on FAO guidelines for soil description (FAO, 2006). Finally, K factor values of the dominant color were assigned to each soil units and the soil erodibility (K) map of the watershed having a grid size of 30 m was produced.

The **K** value varies from **0** to **1**, where the former suggests less and the later imply high susceptibility to erosion risk, respectively (Farhan and Nawaiseh, 2015). The soil erodibility map is shown in Fig. 3.11

Table 3. 8: Soil units, colors and their corresponding K factor value

Dominant Soil Types	Landform Facet	Dominant Soil Color	K value
Lithic Leptosols	Sloping land, crests and ridges, and rock outcrops	Brown or yellowish (7.5YR 4/3)	0.25
Eutric Cambisols	Undulating plains and plateaux	Very dark gray (10YR 3/1)	0.2
Eutric Vertisols	Flat to almost flat topography	Very dark grayish brown (10YR 3/2)	0.15
Eutric Regosols	Rolling plains, side slopes and dissected plateau	Very dark brown (10YR 2/2)	0.15

Source: Modified from Hurni, 1985; Fenta et al., 2016; Gelagay and Minale, 2016

Topographic factor (Slope length and Steepness – LS)

Local topographic factor is the most susceptible parameter of RUSLE in the soil loss estimation (Renard et al., 1997). The LS factor describes the combined effects of slope length (*L*) and slope gradient (*S*), which strongly controls the transport of soil particles. LS represent the proportion of soil loss per unit area on a site to the corresponding loss from a 22.13 m long plot with a 9% slope gradient under otherwise identical conditions. The *LS* factor increased with slope length and slope gradient. S-factor signifies the gradient that controls the flow velocity. The steeper the slope of the land the higher will be the speed and erosive power of runoff (Wischmeier and Smith, 1978; Renard et al., 1997).

Wischmeier and Smith (1978) and Renard et al., (1997) defined slope length as "the horizontal distance from the origin of overland flow to the point where either the slope gradient decreases to a point at which deposition begins or runoff becomes concentrated in a defined channel"

The amount of cumulative runoff increases with slope length. This is because the volume of runoff becomes more and more as it proceeds to the lower slope due to flow received from positions immediately upslope of the point and the flow generated within the point itself (Renard et al. 1997). L-factor was computed by dividing the contribution area by the width over which flow can pass within a grid cell (Oliveira et al., 2013)

Since manual Field measurement and determination of slope in a complex topography is difficult, if not impossible, DEMs were used to drive L and S parameters as suggested by Moore and Burch (1986), Dikau (1989), Mitasova et al. (1999), and Simms et al. (2003). Despite lots of methods are available for estimation of LS factor in the literature, the equations proposed by Moore and Wilson (1992) were adopted for this study to extract LS factor values from a 30 m resolution SRTM DEM data using map algebra expression of Arc GIS raster calculator as shown in equation (3.9). This equation was selected as it has been widely used and tested in several studies in Ethiopia context (e.g. Fenta et al., 2016).

$$\mathbf{LS} = \left(\frac{\beta \chi}{22.13}\right)^{0.5} \mathbf{x} \left(\frac{\sin(\theta)}{0.0896}\right)^{1.3} \tag{3.9}$$

Where, β is flow accumulation, χ is grid cell size (30 m was employed in this study), 22.13 is the RUSLE standared plot length; 0.5 is the exponent of slope length; θ is slope in degrees (i.e. Slope of DEM × 0.01745)

A step wise procedure was followed to generate LS factor map using the hydrology extension spatial analyst tool of the Arc GIS. Since the topography of the study watershed is generally dominated by steep slope areas, a limit was set for maximum slope in order to avoid excessively high slopes perforating into the model. LS map is shown in Fig. 3.11.

Land cover and management factor (C factors)

The C-factor illustrates how different LULC types (such as cropland, forest, grassland, etc) affect soil loss rates (Renard et al., 1997). Estimation of the C factor values in the RUSLE model requires data related to soil management status, the role of plant canopy and crop residues as a soil cover, soil surface roughness, and soil moisture status. However, the evaluation of each of this parameter is difficult due to many possible combinations and scarcity of data (Renard et al., 1997; Farhan and Nawaiseh, 2015).

To assign C factor value of this study, the Land sat-based LULC classes created in 2017 for the watershed was employed. For this end, the watershed was categorized into the required LULC classes and the C-factor values were determined from these LULC maps of the watershed. Then, the raster map was converted to vector format to assign the corresponding C factor value of each land use/ cover class based on available literature recommendations in the Highlands of Ethiopian (Table 3.9). C factor map is depicted in fig. 3.11

Table 3. 9: Adopted C-factors values for different LULC classes in the Ethiopian Highlands

Land-use/cover type	Cover factor	References
Cultivated land (Cereals, pulses)	0.15	Hurni (1985); Bewket and Teferi (2009)
Afro/sub afro-alpine	0.01	Teferi andBewket, (2009)
Bush/shrub	0.05	Tamene et al. (2014); Haregeweyn et al., (2013)

Open woodland/ Plantation forest	0.06	Eweg and van Lammeren (1996)
Bare land/soil	1	Eweg et al (1998), Hurni (1985)
Grassland/ Grazing land	0.05	Hurni (1985); Bewket and Teferi (2009);
Water courses and beds	1	

Source: Compiled by the Author, 2017

Support practice (P) factor

Support practice (P) factor refers to "*the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope tillage*" (Wieschmeier and Smith, 1978; Renard et al., 1997). The P-factor refers to different land use management practices that trim down the erosion potential of runoff concentration, runoff velocity and forces that exerted on the surface of soil (Renard et al., 1997; Panagos et al., 2015). Of all the erosion factors, values for P are the least reliable (Renard *et al*., 1991). This is due to the difficulty in identifying its characteristics in the field.

Google earth, SAS planet software (used to look at high resolution satellite image) and field observations were used in order to investigate the support practice factor (P) available in the watershed. Soil/stone bunds (level/graded), stone faced soil bunds, hillside terraces stabilized and reinforced with tree planting, trenches, diversion ditches, cut-off drains and waterways, stone check dams and gully rehabilitation, establishment of area closure and to a limited extent afforestation and revegetation of degraded and fragile hillside areas have been implement in the watershed. Though it was not widespread, indigenous soil conservation measures such as grass strips (Locally Known as *Weber*) and drainage ditches (to safely guides runoff off-farmlands) have been practiced by some farmers in the watershed.

However, it was witnessed that though sustainable land management program target sites have properly installed SWC structures, the largest segment of the watershed have either poorly designed or totally destroyed support measures. Moreover, as it was observed from the field visits in the watershed, most of conservation structures were widely spaced against technical recommendation and there was no proper maintenance carried out on the previously established structures. Even degraded hillsides which were once restored through project support, currently exposed to degradation due to poor management activities and limited active involvement of farmers and their related institutions in the management process. Therefore, it is not logical to use these support factors as an input data in evaluating soil loss rate in the watershed.

Hence, the watershed was categorized in to agricultural land and other LULC types as suggested by Wischmeier and Smith (1978). Since land management activities are highly dependent on slope classes, agricultural lands were again categorized into six slope classes (Table 4) and for each respective slope class p-values were assigned (Wischmeier and Smith, 1978). While for the other LULC classes in the watershed, a uniform default value of 1 was assigned for the (P) factor regardless of the slope class they have as recommended by previous scholars who carried out comparable research in the Ethiopian highlands (Abate, 2011; Bewket and Teferi, 2009; Gelagay and Minale, 2016; Gashaw et al., 2017).

Table 3. 10: Land management factor (P) values suggested by Wischmeier and Smith (1978)

Land Use	Slope classes (%)	P Factors	References
Cultivated Land	0-5	0.10	Wischmeier and Smith (1978); Hurni (1985); Bewket andTeferi, 2009; Gelagay and Minale, (2016);
	5-10	0.12	
	10-20	0.14	
	20-30	0.19	
	30-50	0.25	
	50-100	0.33	
Other land use	All	1	

Source: Author's Analysis, 2018

The ArcGIS processing tool was employed to generate the thematic map. The values of P factor range from 0 to 1 and lower value indicates relatively better soil erosion control measures. The P value was assigned based on literatures and the previous empirical values adapted to Ethiopian condition (Table 3.10). P factor map is portrayed in figure 3.11.

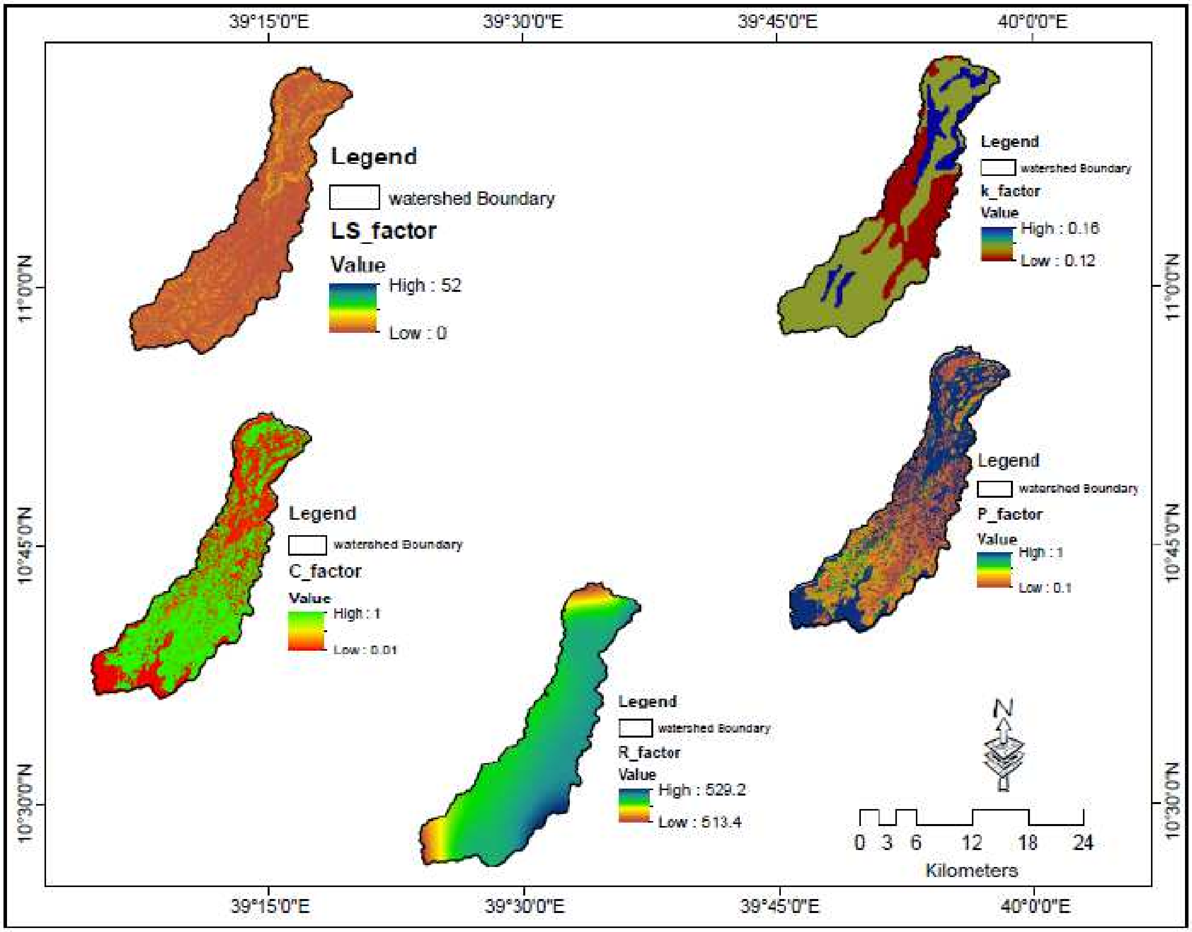

Figure 3. 11: Spatial distributions of LS, K, C, P & R factor on the Gedalas watershed, 2018

3.2.5.2.3 Approaches for Validation of Model Results

Due to lack of previous case studies specific to the study area, the validity of the model outputs was compared with numerical data outputs of similar studies over Ethiopian highlands. Qualitative approach such as use of perception of local communities on soil erosion status was used. To help farmers better explain the severity and onsite soil loss occurrence, the appraisal was carried out during the rainy season of the year (Diwediga et al., 2018). In addition, selective field observations were carried out to identify most erosion prone areas. In supporting these processes, the color printed model output soil erosion severity map was taken in the field to check it on the ground and compare the model result with community perception.

3.2.5.2. 4 Data Analysis Techniques

To identify the contribution of each parameter in RUSLE model, each factor was calculated as a specific thematic layer on the cell by cell bases (Millward and Mersey, 1999). Since both the Landsat images and the DEM used in this study had 30 m spatial resolution, all the required data layers were co-registered to a common pixel resolution and datum. After completing data input procedures and arranging each information layer, the mean annual soil loss was calculated by multiplying each factor layers together according to the RUSLE formula (Equation.1) using the raster calculator of map algebra functions and associated packages in a GIS framework.

Then, the estimated annual mean soil loss rates were displayed in map showing spatial distributions of erosion risk for the watershed and details of statistical soil erosion intensity classes and ranges of soil loss rates were identified and categorized following the FAO soil description guidelines (FAO, 2006) and expertise judgment, with some modification to suit the local condition of the watershed as depicted in Table 5. Finally, the spatial differences in rate of soil erosion in relation to corresponding LULC categories, slope classes and agro ecologies were evaluated by using the zonal statistics function of the spatial analyst tools in ArcGIS software and the results were supplemented by local community perceptions.

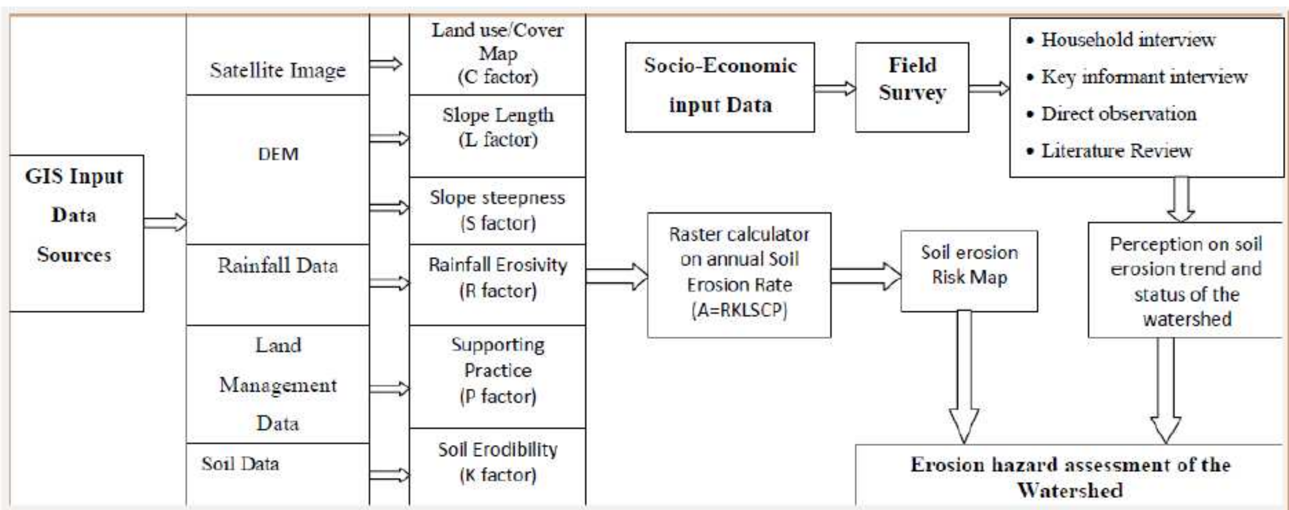

Figure 3. 12: The overall sequential step employed to estimate soil loss by RUSLE Model

3.2.5.3 Method for Soil survey and Analysis

3.2.5.3.1 Soil sampling, storage and preparation

Since soil sampling and analysis is costly, it is not realistic to take sample in every field. First the entire watershed was sub divided and delineated in to three agro-ecologies (Wurch, Dega and Weyna-Dega) depending on altitude. Due to limited funds for soil laboratory analysis, three dominant land use/cover types (croplands, grasslands/grazing lands and shrub lands) were purposively selected. To determine the final sampling sites, similar soil types, topography and similar land use history were taken in to consideration (Zapata, 2002). For soil sample collection, the cluster sampling procedures applied by Abegaz et al., (2016) was modified and used for this study. In order to address effective root depth of most crops, representative soil samples were taken from the top 20 cm depth in a radial sampling scheme using soil auger. The top 20 cm were selected purposively as this part of the soil assumes to contain the highest concentrations of many of the soil constituents and has the strongest response to land use variations; and so, is likely to be most vulnerable to soil degradation (Abegaz et al., 2016).

Other important aspects of soil sampling are the size and number of samples must be representative of the soil under study. In view of these premises, maximum care was taken to address soil heterogeneity and spatial variability during collection of soil samples. Hence, for those land use types having uniform topography and homogenous soil type a minimum of 10 sub-samples were collected and composited within 10 to 100 m distance between each sub-plot using random sampling technique. Under heterogeneous landscapes where slopes and soil type vary in short distance, the numbers of sub-sampling points were extended up to 15 within relatively short distance that ranges from 10 to 20 m between and among each sub-sampling points.

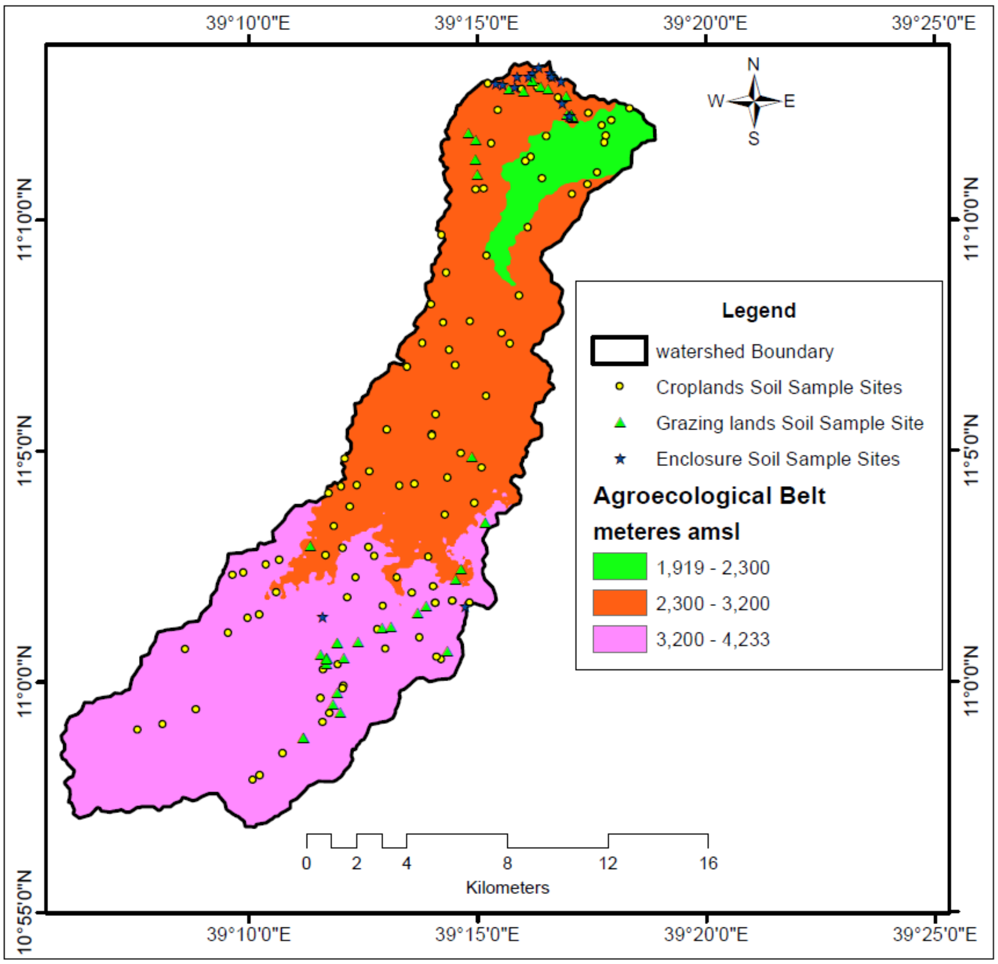

Figure 3. 13: Examples of distribution of soil sample points on the watershed

During soil sampling, site related information such as name of the soils in the local language; physical characteristics of the sampling sites such as slope gradient, elevation, LULC types, dominant crop growing in the area, the presence /absence of SWC measures, type and rates of fertilizer used, cultivation and grazing history were noted from local farmers and through visual inspections. Slope gradient and elevation were measured by using clinometers and Global Positioning System (GPS) respectively. All thus data were recorded on the field check list (Appendix 1E). While taking samples non representative areas were excluded. Samples were collected using standared equipments and buckets were used to keep and mix-up it.

Composite soil sample was then prepared from the sub-samples for each representative agro-ecologies and LULC types. In this way, a total of 27 different soil samples (three LULC types × three agro ecologies × three replications) were collected. The soil samples collected from each LULC types were air dried by spreading out the soil on a plastic bucket; clumps were crushed, and thoroughly mixed to homogenize. Utmost care was carried out in order to reduce contamination of samples. Before sampling, unwanted debris and any other irrelevant materials were removed from sampling. Finally, 500g sub-samples were re-sampled from each pool, transferred and packed into clean plastic bags for laboratory analysis. On each bag, a label was attached showing site names and locations. The bags containing the samples were properly stored and transported to the lab for subsequent physicochemical analysis.

3.2.5.3.2 Soil Laboratory Test

Soil samples taken from 27 sites stratified by agro-ecology and land use type were analyzed for the following physicochemical parameters: soil texture, bulk density, particle density, pH, Electrical Conductivity, Exchangeable bases, Cation Exchange Capacity, Organic Carbon, Total Nitrogen, Available phosphorus, available potassium, available Sulfur, and available sodium. Laboratory analysis of soil samples were made as per selected LULC types and agro-ecologies. All the soil samples were analyzed at the same laboratory to allow cross site comparison and to avoid variation of results from various laboratories. Accordingly, analysis physicochemical properties were carried out in the Ethiopian construction design and super vision works corporation; Water and Energy Water Design and Supervision work sector Laboratory Service in Addis Ababa (**Appendix 3**).

Bouyoucos hydrometer method was employed to determine proportion of of particle size distributions (Bouyoucos, 1962). FAO textural classification approach was applied to determine the textural class (FAO, 1998). Soil bulk density was determined with indirect method in the laboratory after drying the soil samples in an oven at 105°C to constant weights (Al-Shammary et al, 2018) while particle density was measured by the volumetric method (Black, 1965). Total porosity of the soil was derived from the bulk density (BD) and particle density (PD) (Brady and Weil, 2002) as:

$$\textbf{Total pore space (\%)} = (1 - BD/PD) \times 100 \qquad \textbf{(3.10)}$$

Soil pH and electrical conductivity (EC) were determined in 1:2.5 soils to water ratio using probe metod (Reeuwijk, 1993). The Organic carbon content was measured by wet digestion method as described Walkley and Black (1934) and percent of soil organic matter was computed by multiplying the percent soil organic carbon by a factor of 1.724 following the assumptions that average content of carbon in soil organic matter is 58% (hence, 100/58= 1.724). Total nitrogen (TN) was determined by micro Kjeldahldigestion, distillation and titration procedures as described by Black (1965). Available phosphorus content of the soil was determined using Olsen extraction method (Olsen *et al.* 1954; Olsen and Dean, 1965), as this test is the proven methods for P extraction under different pH value elsewhere in the world including Ethiopia (Tekalign and Haque, 1991). Cation exchange capacity (CEC), Exchangeable bases (Ca, Mg, K and Na) and available potassium were determined with ammonium acetate solution and instrumental methods such as atomic absorption spectrophotometer and flame photometry (Black et al, 1965; Chapman, 1965; Rowell, 1994).

3.2.5.3.3 Data Analysis

Before analysis, test of normality was carried out to identify and filter outliers. Extreme values were expelled from further analysis. Statistical analysis was undertaken using SPSS Version 20.0 software for window. A one-way analysis of variance was used to compare the mean soil test values between the different LULC types and agro-ecologies. Least significant difference (LSD) post hoc comparisons were conducted to test for differences. Five percent probability level ($p < 0{\cdot}05$) was employed to detect significant differences. Pearson's correlation analysis was also performed for some possible paired combination of the variables in order to determine the relationship between the selected soil physicochemical properties and within and among LULC types and agro ecologies. Soil nutrient status of the watershed were evaluated against the threshold/critical values indicated in Landon (1991) for tropical soils, in FAO (2006b) for integrated nutrient management and in EthioSIS (2014) for Ethiopia Soils.

3.2.6 Methods for Socioeconomic Data Collection and Analysis

3.2.6.1 Household Selection: Sampling Frame, Sample Size and Sampling Procedure

3.2.6.1.1 The Sampling Frame

The study was focused only on the upper sub catchment (Gedalas watershed) of the Beshillo River. Hence, the sampling frame is farming communities living in the watershed. The NGOs, government agencies and other related stakeholders working on the resources management in the area was the subject of the study too.

3.2.6.1.2 Sample Size and Sample Allotment Procedures

Given a larger geographical coverage of the study watershed, it is not possible to reach out to all households. Thus, the researcher had to select specific sample households to work with. The decision on the sample size is dictated mainly by the objective of the study, the characteristics of the territory and the heterogeneity of the community,representativeness, complexity and coverage of the questionnaire, the time available and the resources that are feasible for carrying out the survey (Zapata, 2002; Ryan and

Bernard, 2010). Moreover, the number of samples may depend on the researcher's judgment, required precision, accessibility of significant information out of that number in consideration with time and budget constraints. Nonetheless, for this research, the household heads (at the time of data collection) of the watershed were considered as the survey population and the units of analysis from which information were collected. After recognizing the number of kebeles found in the watershed and identifing their size of household heads living in the watershed, the sample sizes were determined. Accordingly, out of the total 9797 household heads living in the sample kebeles of the watershed, 384 samples size were determined using empirical formula recommended by Yamane (1967) which can be calculated as:

$$\boxed{n = \frac{N}{1 + N(e)^2}} \tag{3.11}$$

Where **n** is the number of samples, **N** is the size total household heads, and **e** is level of precision at the **0.05** significant levels.

3.2.6.1.3 Sampling Procedure

Regarding procedure of sampling, multistage sampling design were employed. In the first stage, the case study watershed was purposefully selected based on the criteria stated so far (see Chapter I). In the second stage, out of the total of eight *Kebeles*[4] that are partly or wholly located in the boundary of the watershed, six *kebeles* were considered for the study. These *kebeles* were preferred because at least half of their territory is situated and their large numbers of residence live within the watershed. Then, sample size for each kebele was determined based on the principle of proportional allocation using the following formula: $n_1 = nN_1/N$, where **n** is total number of samples, **N** is total number of population, $\mathbf{N_1}$ is number of population in each kebeles or village and $\mathbf{n_1}$ number of sample from each kebeles.

Since most of the *kebeles* lies in more than one agroecology, they were further divided up into upper, middle and lower categories and then sample villages were selected purposively based on such agro ecological dimensions. To ensure gender representativeness, first, household heads of each selected villages were stratified into male-headed and female-headed using lists obtained from administrative office of respective kebeles. Then, representative sample farmers were drawn from each proportionate to size of household heads using systematic random sampling.

[4] Kebeles are the lowest administrative units in the administrative structure of Ethiopia.

Table 3. 11: Sample size, along with percentage share based on sex, kebeles and agro ecology

Kebeles	No. of household heads*			Sample size**			Percentage of the total	Agro ecology	Position in the watershed
	Male	Female	Total	Male	Female	Total			
Sengolla	1374	567	1941	54	22	76	20	Dega and W/Dega	Lower and Middle Part
Mitgina	573	103	676	23	4	27	7	Dega and W/Dega	
Mekena	1575	333	1908	62	13	75	20	Dega	Middle Part
Wertej	1938	419	2357	76	16	92	24	Wurch and Dega	upper and Middle Part
Gaya	1219	575	1794	48	22	70	18	Wurch	Upper Part
Haroghie	865	256	1121	34	10	44	11	Wurch and Dega	Upper and Middle Part
Total	7544	1920	9797	297	87	384	100		

* Obtained from TWARDO; ** Selected based on proportion

Source: own sampling scheme, 2016

A purposive sampling technique were used to select participants for key informant and focus group discussion using predetermined selection criteria such as age, gender, and knowledge of the community and the study area.

3.2.6.2 Data Collection Processes: Executing the Field Work

The data Collection Processes was participatory and interactive in which changes were made in the course of data collection whenever necessary (Nelson, 1991). This study was conducted through three main phases. Phase one was the reconnaissance survey, the actual field work was carried out in phase two and the finalization and confirmation processes were taking place in phase three.

3.2.6.2.1 Exploratory field surveys and reconnaissance studies

preceding to the collection of actual field data, reconnaissance field surveys was carried out to get an overview of the general physical environments (i.e. soils, vegetation, climate, accessibility) and community contexts (such as settlement pattern, land-use practices, management aspects and other relevant information) of the watershed. Moreover, identification key actors involved in SLM activities were carried out and informal discussions were made with district officials, local residents and development agents. During the reconnaissance survey, some of the physical features of the watershed were recorded in observation sheets and video camera.

3.2.6.2.2 Socioeconomic Data Collection

Due to the complex nature of population-environment relationships, a mixed-data, which combined both quantitative and qualitative type were collected to take advantage of the inherent strengths and counterbalance inevitable weaknesses of each data type. Data collection methods varied according to objectives, specific research questions and the required data types. Socio economic data were collected through (but not necessarily limited to) participatory research methods, which include household[5] survey (interview schedules with household heads[6]), focus group discussion, in-depth semi-structured and open-ended key informant interviews and actual field observation.

Household surveys / Scheduled Interviews

The construction and design of the survey questionnaire such as instructions, wording, clarity, clues, length, logical sequence, etc of the question were guided by widely agreed general rules for designing questionnaires. The questionnaire encompassed both closed- and open-ended questions and covers a wide variety of themes such as demographic, economic, psycho-social, institutional and environmental issues such as farming systems, different land use and land management practices, factors detrmining adoption/adaption of SLM technologies, level and approaches of community participation in resource management, perception of the achievements and challenges of intervention, attendance of training on land management practices, access to support service such as extension services and other infrastructures (**Annex IA)**. The overall land user's views and perceptions related to the changing circumstances of the environment and rural communities' livelihoods were evaluated based on five-points Likert-type items, with 1 representing very low and 5 very high (Likert, 1932). Prior to the administration, questionnaires were pre-tested with 20 randomly selected interviewees, who were not participating in this research, to ensure relevance, validity and reliability. This helps avoid data contamination effects that might have influenced Scheduled Interviews.

Questionnaire administration

Detailed one-on-one scheduled interviews were carried out with 384 household's heads in local language, Amharic. The households' heads were targeted for household survey with assumption of their leading role in decision-making on vital issues, including land management strategies. In case when a household head was unavailable or unwilling to be interviewed a substitute of comparable attributes was replaced through random selection techniques from neighboring household heads. Interviews were carried out by the trained development agents and primary school teachers (with close supervision of the principal author) working in the watershed, who have knowledge about the area and are well acquainted with culture of the local communities. Interviews and discussion sessions were facilitated by the chairpersons and development agents of the respective kebeles. Complete orientation was given for assistants about the

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[5] The term household reperesents persons that share the same abode for an extended period of time

[6] The heads of the households are those who make the implicit decision on farm management activities.

content of the questionnaire, norms of contacting respondents, approaches for conducting interviews, interview procedures, how to probe during the interview processes, how to record responses and other related issues.

To easy identify who administered what questionnaire, the questionnaire was first numbered from 1-384. Each enumerator was given the questionnaires in sequence and the number of questions and the range of questionnaire numbers given to each of the enumerator were registered in front of their names. For any ambiguity, frequent discussion was made at the moment of data collection. Finally, all collected questionnaires were properly returned and encountered problems were thoroughly discussed.

Key Informant Interview

Key informant interviews were performed at the household and institutional levels. At the institutional levels, government actors involved in watershed management, community leaders, woreda experts, local elected representatives and development agents were among the key informants. More than twenty woreda level staff key informants from sector of natural resources management, crop protection, input supply, planning commission, livestock resources development, food security, land administration and use, extension, head of agriculture and Wereda administrator offices were interviewed (**Annex IB)**

The community key informants for in depth interview were local elders (55 and above years of age) who have passed his/her lifetime in the watershed. This is due to their long-term experience on past and present perspectives of the study site. Their selection was based on combination of purposive and snowballs sampling in consultations with knowledgeable local people, development agents and Kebele council members of respective kebeles in the watershed. This sampling approach is recommended by Robinson (2014) to identify and selected information rich respondents for an in-depth case study. Accordingly, fifty elders were selected from the six kebeles of the watershed (Table 3.12). An attempt was made to include male and female participants as well as model farmers.

The interviews with key informant were conducted by the principal author at different times (of the year 2016/17) and took almost two months. The time spent on each interview was on average two and half hours (most were generous with their time) and the interviews were conducted in a variety of settings such as at homes and watershed sites where soil and water conservation activities were taking place. Some interviews were also conducted at farmlands and sites of grazing lands where people herding livestock which enable the author to observe livelihoods-environmental interactions.

Interview guide checklists (**Annex IC)** comprising both open and close ended questions were employed. The open-ended questions were designed to generate detailed information through further discussions on specific issues while the closed questions were asked to elicit definite answers.

The interviews dealt with a wide range of predetermined questions addressed historical change in LULC, household land use and land management practices; perceptions on the historical trend and the status of land degradation problems and restoration efforts in their surroundings; contemporary watershed management practices, strengths and weakness of the implementation approaches and its impact on biodiversity and general land productivity; issues surrounding their livelihoods assets and strategies; initiatives in the watershed management activities; their experiences in land tenure arrangement policies; their experiences and responses to climate changes and variability and other relevant data. Due to absence of baseline data, the study was retrospective, capturing information about the situation by reviewing previous reports and interviewing of local communities based on before and after approaches.

To reduce wrong and bias responses caused by recall error for retrospective questions, various memory cues (memorable events) and reference period such as event calendar (natural disasters, government changes and other memorable historical events) were used as a benchmark and signal posts for discussion. These interviews with various individuals were continued until information saturation point was reached that is until no new themes were emerged.

Table 3. 12: In depth Interview Sites and Participants in the watershed by kebeles

S/N	Data Collection Site @	Number of key informant Participants in the community			Number of Participants in FGD in the community		
		Male	Female	Total	Male	Female	Total
1	Sengolla	8	4	12	8	3	11
2	Mitgina	7	2	9	6	2	8
3	Mekena	10	2		6	4	10
4	Aroghie	5	3	8	7	3	10
5	Wortej	8	3	11	8	4	12
6	Gaya	7	3	10	6	3	9
	Total	45	17	62	41	19	60

@Each kebeles stride on one or more sub watersheds

Source: Field survey, 2016/17

Focus Group Discussions (FGD)

In total, six focus group discussions were held with groups of eight to twelve male and female headed households of various ages on three different time periods (Table 3.12). One FGD were conducted in each selected kebeles of the sub watershed to obtain people's perceptions of environmental change, driving forces, impacts on livelihood practices, personal and institutional responses, particularly contemporarywatershed management practices and challenges and impacts on their livelihoods to mention but a few (**Annex ID)**

Arrangement for FGDs was made by the local extension officers to use what the local community considers sacred (non-working day) such as Friday and Sunday for the discussions. Moreover, some occasions such as end of funeral ceremonies were used as an opportunity to collect information from participants. On the process of discussions women were encouraged to shun cultural dominance of men over women so as to ensure and adequately captured the views of women. The discussions were guided with checklists of discussion topics. During the discussion sessions, participants were given an open opportunity to raise and elaborate their understandings and concerns on any related issue until saturation of ideas. Each focus group discussion took on average three hours. The participants deliberate on the discussion issues commented one another and provided historical accounts on the discussion topics based on their own environmental experience and knowledge.

This approach is very important to cross-validating information and filter out controversial and contested issues through debate and dialogue on the topic of interest. These kinds of discussions were also important to balance exaggerated or underestimated views that might be given by some individuals.

Participatory Assessment and Transects Walks

The participatory transect walks and participant onsite observations were conducted to triangulate information obtained through household survey, Key-informant interview and focus group discussion and in order to get acquainted the real situation on the ground. In each sub watershed, at least one day transect walk were deliberately carried out with local residents and development agents. During the walk, on-farm observation and discussions were made with farmers working on their plots to get further clarification on the LULC history; vegetation density and species diversity; perceived impacts of SWC technologies; local soil types and fertility status; use of farm inputs such as organic and inorganic fertilizers; pesticides; the general farming system; the cropping pattern and erosion risk; overall trends of environmental changes and livelihood constraints of the area were noted. Along with this, dominant woody vegetation types, species composition and the extent of vegetation degradation were observed and noted and photograph was taken for further analysis and interpretation.

Accessing most parts of the watershed was not an easy task as they were far away from the main roads. In addition, rough topography and the slippery nature of the terrain prevented to use vehicle away from the main road during data collection and so data collectors had to ride mule or horse and walk the rest on foot. However, the beautiful scenery of the topography, and welcoming approach of the rural community compensated the challenges and motivated the researcher and assistants to pursue the process of data collection.

Figure 3. 14: **Way of transport during data gathering and on-site observation (the researcher in the field)**

Secondary Data

To supplement the primary information, additional data were collected through a review of relevant literatures, archival data, policy documents, guidelines, and legislation from various government sources. Moreover, census reports, statistical abstracts earlier research results, conference proceedings, funding documents, project proposals and implementation reports, journal articles were referred.

Both website and hard copy sources of literatures were used to collect relevant literature and other documents. Landholding size, demographic aspects, cropping pattern and watershed activity report was collected from Wereda agriculture and natural resources offices. Several key words such as land degradation, SLM, SWC, integrated watershed management, soil fertility management, livelihood, food-for-work, Productive safety net and so on were used in searching electronic literature.

3.2.6.3 Socioeconomic Data Processing, Analysis and Interpretation

This section focuses on socioeconomic data processing method. A mixture of qualitative and quantitative analysis approaches and procedures were used.

3.2.6.3.1 Analysis of Quantitative Data

In analyzing quantitative data, both descriptive and inferential statistical methods were applied. The data collected through questionnaires were organized, assembled, classified the mass of data, coded, cleaned, verified, and entered into a computer software for further processing and statistical analysis. Descriptive statistics were used to describe the socio-economic attributes of the respondents. The frequencies for all the relevant variables were computed and presented in tables and percentages. Cross tabulations were used tests differences between different variables and among categories of respondents.

Statistical Package for Social Scientists (SPSS) software was used to define the variables and enter the coded data into SPSS program. In addition, the statistical parameters such as means, standard deviations and correlation analysis were employed when ever found appropriate.

Moreover, qualitative data were also used for quantitative analyses. For example, the results of a survey requesting likert scale response alternatives were analyzed by calculating a composite score. Average weightings approaches were used to accommodate variations in farmers' perceptions on the relative potentials and limitations of each evaluating criterion (by giving scores to each criterion) on various SLM strategies. Selected graphs and shorter tables were displayed in the main text where as denser statistical tables and some supplementary data were presented in the annexes.

3.2.6.3.2 Analysis of Qualitative Data

Data collected through qualitative methods were organized, summarized and analyzed in a thematic approach. This includes the information obtained through literature reviews (example, documents review from national and regional archives, photographic evidence and other qualitative sources), field observations, in-depth case studies, key informant interviews and focus group discussions. From the analysis, similar themes on selected aspects of the investigations were grouped using **atlas. ti** software for subsequent discussion. The results were interpreted based theoretical ideas underpinning the research and research questions. Where appropriate, actual statements of the respondents obtaining during the group and individual interviews were reported to illustrate and support points of view expressed by the informants. Sustainability analysis is done by comparing the parameters set by the watershed guideline and sustainable land management principles with the findings of real field conditions. Literature from similar studies was consulted to assess the reliability of results.

3.2.6.4 Methods Used for Logistic Regression Model

3.2.6.4.1 Variables Description

Though the degree of implementation and use diversity of SLM practices varied from farmers to farmers, for this study, the dependent variable was dummy variable that takes a score of 1 or 0 depending on whether or not the respondents actually practiced at least any one or a combination of commonly practiced land management strategies, namely, soil erosion control measures and/or soil fertility and crop management practices of any type on their cultivated lands. A value of 1 was allotted to all households who actually implement and 0 otherwise.

A total of 20 endogenous and exogenous explanatory variables that were expected to influence actual implementation of SLM practices were considered in the model. The selection of predictor variables used in this study was based on review of the literature (e.g., Kassie et al., 2014; Teshome et al., 2015; Nigussie et al., 2017) and the author's knowledge of the studied area. These variables were loosely categorized into four groups: plot level characteristics (e.g. farm Size, plot's slope, perceived level of soil fertility status, land fragmentation, plot distance from farmer's residence); personal and household attributes (e.g. age, sex, and education level and labour forces availability); socio-economic attributes (e.g. size of livestock, off-farm income, participation in labour sharing and mutual assistance practices) and institutional support and farmer's level of perception (e.g. access to credit and project intervention, land tenure security, and access to SLM-related information and perceived importance of SLM practices were the main expected predictor variables influencing the implementation decision of SLM practices in this study area. These variables were assumed to potentially affect farmers' SLM implementation decision. . However, no a priori assumption was made about the direction and magnitude of the influence of the variables as the author believed that out put itself indicate the directions.

3.2.6.4.2 Empirical model Selection and Explanation

There are a range of statistical techniques used to assess factors influencing the farm household's decision to actually implement SLM practices. Since our dependent variable is dichotomous and the independent variables are continuous and dichotomous, binary logistic regression model was preferred in this study (*Appendix 4*). The advantage of using logistic regression is that it makes no assumptions about the distribution of the predictor variables. The model also ensures that the estimated probabilities will lie between the logical limit of 0 and 1 (Tesfaye et al., 2013). Moreover, logistic regression is not only simple to calculate and very easy to interpret but also important as it avoids confounding effects of variables by analyzing the associations of all variables together (Sperandei, 2014). It was against all these reasons we necessitate to apply binary logistic regression model for this study.

Following Peng et al (2002), the logistic regression model employed in the study is presented in equation below:

$$\ln(Y) = \ln\left(\frac{Y}{1-Y}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots + \beta_n X_n + u_i \tag{3.12}$$

Where,

Y= The predicted probability of the event (farmers' actual implementation of SLM practices), which is coded with 1= implementing; and 0= not implementing

1 − Y= The predicted probability of the other decision (non-SLM implementing farmers)

β_0 = Constant

β_n = Coefficients of explanatory variables

X_n = Predictor variables (can be categorical or continuous)

U_i = Error term.

3.2.6.4 .3 Model Evaluations

Model evaluation was performed to test goodness-of-fit and validity of predicted possibilities (Peng et al, 2002). Goodness-of-fit statistics was assessed to test the fit of a logistic model against the data. It was assessed using Hosmer–Lemeshow test as it allows for continuous and dichotomous variables (Bewick et al., 2005, Field, 2009). The classification table method was employed to assess the predicted and observed scores observations (Hosmer and Lameshow, 2004, Field, 2009). The higher the percentages, better fit the model is.

3.2.7 Ethical Consideration

The research was conducted in an ethical manner. Before the actual beginning of research activities, site permission letter was obtained from district level concerned institutions to conduct this research in the area. Local officials and respected elders of the society were approached in order to get their good will and develop trust among them. Every precaution was taken while collecting data from the respondents. Individual interviews were proceeding only after the prospective respondents had been introduced into the focus and purpose of the research as well as the amount of time they expected to spend. To minimize hesitate and develop confidence among interviewee, the respondents were assured that all interviews were guaranteed confidentiality and anonymity. Oral consent was obtained from all participants prior to commencing the interview and discussion. Oral consent was considered to be more appropriate since most respondents may not understand/read written consent forms.

To respect their rights and privacy, respondents were confirmed that they were free to abstain from answering the questionnaire or to avoid answering specific questions with which they were not comfortable. In the process, due respect and attention were given to the culture, norm and way of life of the community in which this research was conducted. Necessary permission was sought when photographs were taken in places where it is needed. No one was photographed and recorded without his/her consent.

Informal discussions were held with the concerned district officials, agricultural experts, DA's and key informants in order to let them know the findings and check whether the finding have misrepresented their views and to consider comments or suggestions on the final result of the research. Hence, *a*s the researcher, I take full responsibility for all the contents and any mistakes herein the document. Furthermore, ethical clearance has been taken from the College of Agriculture and Environmental Sciences (CAES), University of South Africa which was approved by the CAES ethics review committee.

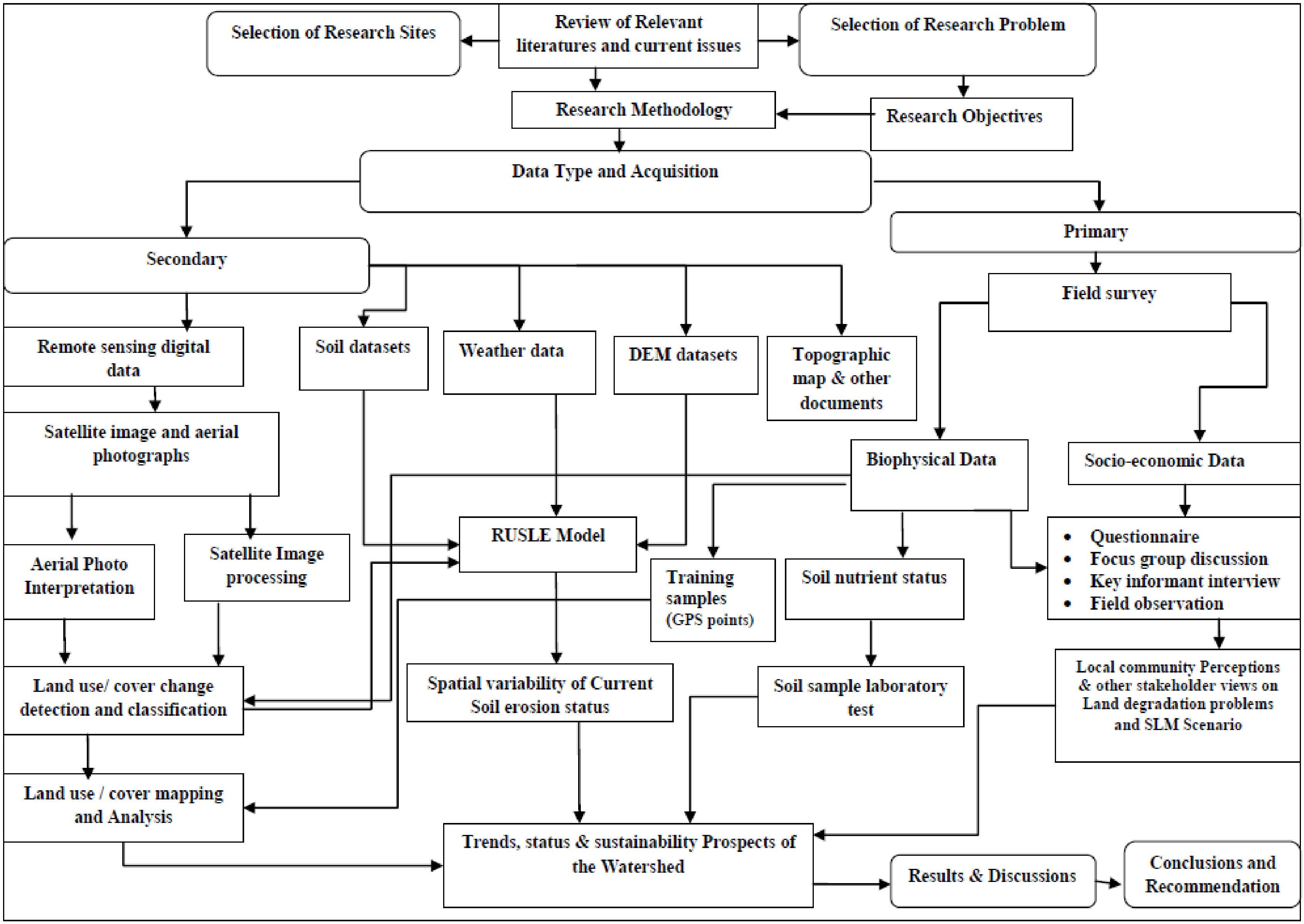

Figure 3. 15: Flow Chart Showing the Sequence of the Research Approach

CHAPTER FOUR

4. Land Use/Cover Dynamics, Driving Forces and implications for Promotion of SLM Practices[7]

4.1. Introduction

As noted in chapter one, land resources, which are an integral component of the watershed ecosystem, are essential platform on which human activities take place and also the source of materials needed for these activities. However, land is becoming a limited resource subject to competing demands and its various functions and services are seriously compromised by the problem of human induced land degradation. Despite LULC change have social and economic benefits this dynamic and complex process usually has an unintentional interlocked multidimensional consequence upon essential functions of the Earth's ecosystem services at both the small and large scales. The current status of LULC is the result of an evolving process rooted in the past and the impact of past legacies on the organization and operation of present LULC senarios. Hence, periodic LULC change monitoring is an essential requirement and vital input for the evaluation of ecosystem health, to judge whether the proposed land management practices have been achieved or not and investigates factors responsible for triggering the dynamic processes and assesses the environmental consequences of such changes.

Moreover, information on LULC dynamics assists in monitoring environmental changes and developing effective land use management and planning strategies at both national and local levels. This chapter portrays LULC dynamics, the driving forces and over all socio-economic and environmental implications associated with these changes by integrating remote sensing data and the insights of the local communities.

4.2 Spatiotemporal patterns of LULC Types in Gedalas Watershed (1973-2017)

The spatio-temporal quantity of LULC types of each category was analyzed in terms of total area and percentage for each study periods (Table 4.5). The result indicated that the proportion of each LULC classes varied considerably on different dates considered. In 1973, the dominant LULC types in the watershed were farmlands/ settlements accounting for more than 50% of the total area followed by Afro/Sub afro alpine vegetation (19.8%), grass lands (16.3%), and shrub/bush lands (10.8%). Bare lands, Woodlands/plantations, and Water courses/ beds comprised the minimum share of the watershed. Though the proportions occupied by each LULC types slightly varied, the order of area coverage remained the same in 1986. In 2001, farmlands and settlements were still the dominant category (48.4%), followed by Afro/Sub afro

[7] Part of this chapter is published as journal article as: Yesuph A.Y and Dagnew A.B. 2019. Land Use/Cover Spatiotemporal Dynamics, Driving Forces & implications at the Beshillo Catchment of the Blue Nile Basin, North Eastern Highlands of Ethiopia, *Environmental System Research,* **8**:21

alpine vegetation (19%) but the ranks of shrub / bush lands (14.8%), and grass lands (12.8%) were reversed. These orders continued for 2017 LULC distributions. The results showed that Farmlands/ Settlements were/are remained by far the dominant LULC of the watershed for the last 43 years in the watershed (Table 4.4).

Table 4. 1: LULC types and area coverage in ha

Land use/Cover Type	1973		1986		2001		2017	
	Area	% of total	Area	% of total	Area	% of total	Area	% of total
Afro/Sub afro alpine vegetation	4738	19.77	4659	19.44	4563	19.04	3513	14.66
Bare lands	397	1.66	425	1.77	520	2.17	613	2.56
Farmlands/ Settlements	12029	50.18	10240	42.72	11601	48.4	12815	53.46
Grasslands	3917	16.34	4470	18.65	3090	12.89	3040	12.68
Shrub/bush lands	2592	10.81	2924	12.2	3548	14.8	3010	12.56
Water courses/ beds	123	0.51	95	0.4	101	0.42	91	0.38
Woodlands/plantations	174	0.73	1157	4.83	547	2.28	888	3.7
Total	23970	100	23970	100	23970	100	23970	100

Source: Interpreted from Satellite Image**,** 2017

4.2.1. Accuracy Assessment of LULC Classification

The overall classification accuracy report of 97, 89 and 96 % were obtained for the 1986, 2001 and 2017 classified images, respectively. Since the values falls above the cut point of the established overall classification accuracy level of 85% (Anderson et al., 1976; Congalton and Green, 2009) with no class less than 70% (Thomlinson et al., 1999), we can conclude that there is an acceptable agreement between the classified image and the ground reality it represents. A kappa coefficient result was found to be 0.96, 0.78, and 0.94, for years 1986, 2001 and 2017 respectively (Table 4.2). The results showed a better concurrence for each of the three classified images (Lea and Curtis, 2010)

Table 4. 2: Accuracy assessments of the year 1986, 2001 and 2017 classified images

Land use/Cover Type	1986		2001		2017	
	User accuracy	Producer accuracy	User accuracy	Producer accuracy	User accuracy	Producer accuracy
Afro/Sub afro alpine vegetation	96	100	85	73	95	100
Bare Lands	88	88	71	56	100	83
Farmlands/Settlements	96	96	91	96	98	95
Grass Lands	100	95	90	86	97	97
Shrub lands	98	96	88	94	93	96
Water courses and Beds	100	100	100	100	0	100
Woodlands/Plantations	90	100	67	76	91	91
Over all accuracy (%)	97		89		96	
Kappa coefficient	0.96		0.78		0.94	

4.2.2. Land use/land cover changes in Gedalas Watershed since 1973

The LULC changes were classified into four Consecutive periods 1973–1986 (first period), 1986–2001 (second period), 2001–2017 (third period) and 1973–2017 (whole period) (Table 4.5). LULC change diagnostics showed that in the first study period (1973–1986), total area of farmlands/ Settlements decreased from 50.2 percent to 42.7 percent irrespective of gains made from other land use/cover types, but then it showed an overall increasing trend throughout the whole study period with the highest change rate being observed in the period from 2001 to 2017 (Table 4.4). The reduction in the first study period was most likely due to abandonment of farmlands by farmers for reasons of resettlement program of the government to mitigate severe land degradation and historic drought episodes of 1984/85 which had a devastating impact on human population and livestock resources of Wollo in general the study area in particular. Such abandoned farmlands were presumably taken over by grass and shrub/bush covers hence the observed increase in this two LULC types in this period.

For example, the famine of wello caused by drought of 1984/85 is still remains as tragic memory to the world community. The following quote taken from the review of Rahmato is a good proof for the recurrent drought problem of the area:

> *The Wello (where the study area is part of it) highlands are on the leeward side of the main rain-bearing winds and thus receive much less precipitation than the highlands in western Ethiopia on the same latitude. Rainfall is frequently unreliable, and on many occasions the belg rains may fail completely, and the Kiremt rains may be short. This has been the process by which droughts and famines have been triggered for countless generations (*Rahmato*, 2001:6)*

The Afro/Sub afro alpine vegetation, which was/is the second dominant cover in its surface area, mostly located on the highest elevation and afro-montane ecoregion and accounted for 19.8, 19.4, 19.0 and 14.7 percents of the watershed in the four consecutive study periods. It should be noted that the Afro/Sub afro alpine vegetation areas exhibited declining tendency in its spatial area coverage in all study periods. However, the greatest reduction occurred between 2001 and 2017 compared to that between 1973 and 2001. This could be ascribed to the continuous expansion of cultivated lands, settlements and grazing lands towards higher elevations which was not historically conducive for these purposes due to relatively difficult accessibility, remoteness, and harsh climatic conditions

As it was noted from the discussions with village elders, some decades ago there was snow covered area in their localities. But recently it is totally disappeared, suggesting that the influence of local climate change in the area is substantial. Interview with local development agents also show considerable agreement that the Afro-alpine ecosystems of the watershed (Locally Known as *Gaussa*) is under strong stress from population increase and associated grazing and cropland encroachment, which poses its own contemporary management challenge. Detailed field checks confirmed that the farmlands/settlements and grazing lands are still being expanded upward towards the afro/sub afro alpine areas almost in all slope classes. The possible drivers behind the the upward expansion of farmlands and settlements could be attributed to rapid warming of local climates which forced the to ever increasing human population to expand their grazing and croplands to the afro-montane ecosystem in greater extent to sustain their life (figure 4.3).In this line, IPCC (2012) pointed out that highland areas of tropical zones are among the areas most susceptible to climate change and variability. Similarly, Simane et al (2013) indicated that tropical highlands are experiencing rapid warming.

It was also noted from onsite observation that considerable areas of the alpine zone were recently allocated for landless youth to till and sustain their life which may greatly impair the hydrological and ecological functions of the mountain ecosystem of the watershed. This assumption is concomitant with the research report of Simon et al (2013) who conclude expansion of cultivation to the alpine zone of Choke mountain watershed as the result of population pressure.

By comparison, the proportion of shrub/bush lands showed an increasing trend in the first and second study period, increasing from 2592 ha in 1973 to 2924 ha in 1986 and 3548 ha in 2001. As mentioned above, the increase in shrub/bush land area is presumably attributed to gains from farmlands and grasslands due to devoid of inhabitants for reasons cited above. In contrast to the changes witnessed in the first and second analysis period, the area of shrub/bush land showed decreasing trend after 2001. This could be attributed to farmland/ settlement expansions as the result of the reallocation of abundant lands to landless youths and to those who were returned from resettlement (either because of their own initiative or were chased out) and returnee ex-soldiers. This is in line with studies conducted in other similar landscapes of Wollo (e.g. Bantider, 2007).

Regarding the woodlands/plantation change, it did not show specific trends in the study periods and its spatial distribution is characterized by a very high fragmentation. The result showed that before 1970s, the woody vegetation cover of the watershed was almost negligible (less than 1%).

The watershed experienced increasing trends of woodlands/plantation in the first-time interval (1973-1986) particularly after 1980 which increased more than threefold of its initial cover of the watershed's area (i.e. from 0.73 percent in 1973 to 4.83 in 1986). The apparent increase of woody biomass in the first study period is likely to be a result of early 1980's degraded land rehabilitation and massive conservation efforts policy of the *Derg* regime (backed by significant international support) through enclosures of hillsides, tree-planting campaign and the planting of eucalyptus trees by private farmers. This indicates that, in addition to the national-level continuous endeavor in tree planting, forest protection and conservation, the local government has made enormous efforts in ecological protection.

However, the woodlands /plantation cover declined gradually from its highest level of 4.8% (1157ha) in 1986 to 2.3% (547 ha) in 2001. The decline in woodland/plantation is attributed to the cropland expansion, widespread cutting down of trees for construction purpose timber, charcoal production and firewood consumption. This period also corresponds to regime change. According to local informants, there was devastation of enclosures especially by free grazing and excessive wood harvesting by the local communities during the civil war particularly from 1990 to 1991 since there was no formal government institutions to control the destruction of natural resources. Even during the transition period (1990-1995), there were no strong government environmental policies and institutions. Discussions with expert informants and local elders further revealed that the destruction was highest on Government-controlled forest sites including enclosures during the 1991 government change. This finding was in line with the research report of Bantider (2007) and Woldeyohannes et al., (2018) conducted in eastern escarpment of Wollo and Abaya-Chamo Basin of southern Ethiopia respectively. For instance, Bantider (2007), quoting one of the then forest expert of the Wereda, stated that "*as the result of power vacuum, community forest of eastern escarpment of Wollo were ruthlessly exploited and deforested by the community to the extent of uprooting*".

While the overall rate of change is in a monotonic manner, the study finds an increasing tends in woodlands/plantation after 2001. This encouraging result can be ascribed to the administrative regulation of the implementation measures on carrying out a nationwide watershed management campaign and the "rural land administration and use proclamation" issued on 15th July, 2005. The proclamation stipulated the implement protection measures for rural lands, including limited forest harvesting, planting trees on sloppy hillsides, prohibit free grazing, promote soil and water conservation and water harvesting. These circumstances may not only the driving factors to improve the ecological environment, but also the reasons for LULC change in the watershed.

As reported by the elderly people and verified in the field, the ongoing community-based watershed management interventions and SLM program seems contributed a lot for the improvements of the vegetation cover of the watershed. The enclosed parts of the watershed also showed rehabilitation tendency most likely due to prevention from livestock and human interferences. The statistic table for areas of various LULC types and the spatial distribution of LULC categories for each study periods are presented in Table 4.1 and Fig. 4.1; respectively.

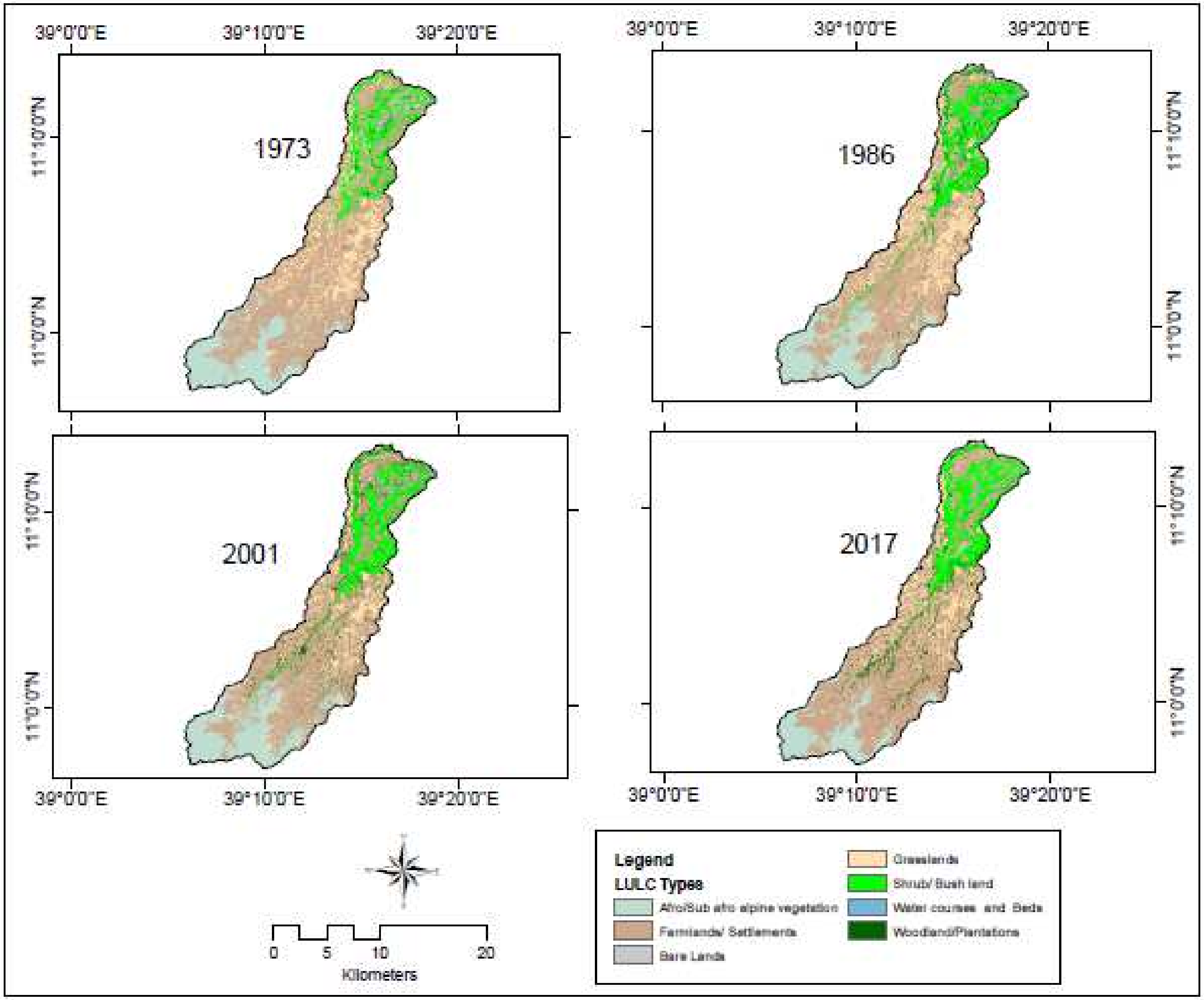

Figure 4. 1: Spatial Patterns LULC of Gedalas Watershed produced from satellite image, 2017

4.2.3. LULC Inter-Category Transitions in Gedalas Watershed (1973-2017)

Though the rate of overall change showed periodic fluctuations; the Gedalas watershed has experienced intricate LULC transitions derived from natural factors and human mismanagement of resources over the last four decades of the study period. The LULC changes were inspected using the post classification transition matrix. For this effect, we overlay the 1973 map with the 1986 map, 1986 map with the 2001 map, 2001 map with the 2017 map and then the 1973 map with the 2017 map to generate four matrixes (Table 4.3).

These matrixes were used to compute the area of gains, losses, persistence and swapping between LULC types. The analysis result at different periods revealed that most these changes were dynamic and non linear, that is, the change from one LULC types to the other does not follow a similar pattern. The change rates for each LULC type in the watershed during the periods were not the same. For instance, between 1973 and 1986 grasslands gained the most, followed by woodlands/plantations and shrub/bush lands while substantial decline was observed for farmlands/settlements. In the second-time interval (1986–2001), the major gains were made by woodlands/plantations, farmlands/settlements and shrub/bush lands. The area of farmlands/settlements increased steadily mainly at the expense of grass lands, woodlands/plantations and afro/sub afro alpine vegetation which contradicts with report of Bewket and Abebe (2013) who documented the expansion of grassland and vegetation cover along river sides in Gish Abay watershed in the Blue Nile Basin. Similarly, shrub/bush lands expanded progressively primarily at the expense of woodlands/plantations (Tables 4.3). Likewise, bare lands and stream courses/beds showed relative increase, while the remaining categories showed declines in which the largest decline observed in grass lands followed by woodlands/plantations. The increasing demand for cultivated lands might have contributed to the decline of grasslands. The result agreed with the findings of Bewket (2002) in Chemoga watershed of Northwest Ethiopia and Tesfaye et al (2017) in Maybar sub watershed of Northeast Ethiopia. However, it contradicts with the finding of Zeleke and Hurni (2001), who accounted an expansion in grassland cover in the Anjeni area, Northwest Ethiopia. The decline of grassland in the watershed would trigger shortage of animal fodder and this in turn resulted in declining of quality and quantity of livestock. This led not only to shortage of services obtained from livestock (e.g. for plowing, traction and transportation) but also has a negative implication on the availability of manure to maintain soil fertility.

In the period 2001-2017, farmlands/settlements, woodlands/plantations and bare lands demonstrated a relative expansion at the outlay of afro/sub afro alpine vegetations, shrub/bush lands and whilst the other classes illustrated relative reduction from their initial states; i.e. 2001. The farmlands/settlements showed the rapid expansion as compared to the other LULC classes. This is likely because of pressure from population growth and decline in productive potential of the existing lands forced the farmers to further expand to mountainous areas and marginal lands.

The change in the area of afro /sub afro alpine vegetation was negative in all four study periods. The decreasing rate of afro/alpine vegetation reached the highest value in the third study period. If we compare LULC change status of the initial and final study years (1973–2017) for each LULC categories, the greatest losses occurred in afro /sub afro alpine flora with a net loss of 1528 ha since 1973. The maximum gains were made by farmlands/settlements and Woodlands/plantations with a net gain of 786 ha & 714 ha respectively over the analysis period. The largest changes were involved in farmlands/settlements and afro /sub afro alpine LULC types as they cover the large parts of the watershed. The largest transitions in this period were from afro/sub alpine vegetation to farmlands/settlements (1007 ha), farmlands/settlements to shrub/bush land (880 ha), shrub/bush to plantations/woodlands (733 ha), grasslands to farmlands/settlements (689 ha), Afro/sub afro alpine vegetation to shrub/bush lands (606 ha), grass lands to shrub/bush lands (393 ha) and farmlands to bare lands (200 ha) (Table 4.3).

This finding is in line with most past and recent Land Use/ Cover Dynamics research reports conducted within the various watersheds of Blue Nile basin and other parts of the country (Bewket and Teferi, 2009; Tsegaye et al., 2010; Fisseha et al, 2011; Kindu et al., 2015; Abate and Lemenih, 2014; Mekasha et al., 2014; Ariti et al., 2015; Zewdie & Csaplovics, 2016, Gashaw et al., 2017) who documented continued expansion of farmlands/settlements at the expense of other LULC types particularly that of natural vegetation. However, there are also other studies which assert the opposite of these study reports. For example, the finding of Tegene (2002), Ermias (2015); Adugna (2015) and Tesfaye et al (2017) confirmed that there was no significant expansion of farmlands in their respective studies in the Ethiopian highland watersheds. **Table 4.3** summarizes the LULC transition matrix in which the diagonals of each matrix displays the proportion of land use classes that showed persistence while the off-diagonal entries comprise the area converted from one LULC classes to the other categories between time1 and time2. The sum of each column shows total area in Time1 for each LULC type. The sum of each row shows total area in time2.

Table 4. 3: The Summary of LULC transformation matrixes in the watershed

	To 1986											
From 1973	Afro/sub Alpine veg	Bare lands	Farmlands/ Settlements	Grasslands	Shrub/bush lands	Water courses/beds	Woodlands/plantations	Grand Total	Gross Loss	change from 1973 (ha)	% of change	Annual rate of change (%)
Afro/sub Alpine veg	4496	0	0	216	15	0	11	4738	242	-79	-1.7	-0.03
Bare lands	1	140	0	0	218	8	30	397	257	28	7.1	0.01
Farmlands/ Settlements	93	120	10066	550	980	0	220	12029	1963	-1789	-14.9	-0.57
Grasslands	67	26	76	3626	100	0	22	3917	291	553	14.1	0.18
Shrublands	2	120	82	66	1467	10	845	2592	1125	332	12.8	0.11
Water courses/beds	0	11	0	0	39	73	0	123	50	-28	-22.8	-0.01
Woodlands/plantations	0	8	16	12	105	4	29	174	145	983	564.9	0.32
Grand Total	4659	425	10240	4470	2924	95	1157	23970				
Gross Gain	**163**	**285**	**174**	**844**	**1457**	**22**	**1128**					

	To 2001											
From 1986	Afro/sub Alpine veg	Bare lands	Farmlands/ Settlements	Grasslands	Shrub/bush lands	Water courses/beds	Woodlands/plantations	Grand Total	Gross Loss	change from 1986 (ha)	% of change	Annual rate of change (%)
Afro/sub Alpine veg	4475	0	144	15	25	0	0	4659	184	-96	-2.1	-0.03
Bare lands	0	320	0	5	97	3	0	425	105	95	22.4	0.03
Farmlands/ Settlements	48	0	9845	4	337	6	0	10240	395	1361	13.3	0.44
Grasslands	40	0	1050	3049	288	2	41	4470	1421	-1380	-30.9	-0.44
Shrublands	0	200	57	7	2305	14	341	2924	619	624	21.3	0.20
Water courses/beds	0	0	0	0	21	74	0	95	21	6	6.3	0.00
Woodlands/plantations	0	0	505	10	475	2	165	1157	992	-610	-52.7	-0.20
Grand Total	4563	520	11601	3090	3548	101	547	23970				
Gross Gain	**88**	**200**	**1756**	**41**	**1243**	**27**	**382**					

	To 2017											
From 2001	Afro/sub Alpine veg	Bare lands	Farmlands/ Settlements	Grasslands	Shrub/bush lands	Water courses/beds	Woodlands/plantations	Grand Total	Gross Loss	change from 2001 (ha)	% of change	Annual rate of change (%)
Afro/sub Alpine veg	3308	0	1173	77	5	0	0	4563	**1255**	-1050	-23.0	-0.34
Bare lands	0	517	0	0	3	0	0	520	**3**	93	17.9	0.03
Farmlands/ Settlements	4	0	10706	0	891	0	0	11601	**895**	1214	10.5	0.39
Grasslands	200	1	40	2817	24	0	8	3090	**273**	-50	-1.6	-0.02
Shrublands	1	1	807	106	2000	0	633	3548	**1548**	-538	-15.2	-0.17
Water courses/beds	0	0	0	0	10	91	0	101	**10**	-10	-9.9	0.00
Woodlands/plantations	0	94	89	40	77	0	247	547	**300**	341	62.3	0.11
Grand Total	3513	613	12815	3040	3010	91	888	23970				
Gross Gain	**205**	**96**	**2109**	**223**	**1010**	**0**	**641**					

	To 2017											
From 1973	Afro/sub Alpine veg	Bare lands	Farmlands/ Settlements	Grasslands	Shrub/bush lands	Water courses/beds	Woodlands/plantations	Grand Total	Gross Loss	change from 1973 (ha)	% of change	Annual rate of change (%)
Afro/sub Alpine veg	2986	0	1007	139	606	0	0	4738	1752	-1728	-36.5	-0.55
Bare lands	0	386	0	0	3	8	0	397	11	216	54.4	0.07
Farmlands/ Settlements	0	200	10907	40	880	2	0	12029	1122	786	6.5	0.25
Grasslands	24	5	689	2806	393	0	0	3917	1111	-877	-22.4	-0.28
Shrublands	0	17	208	47	1579	8	733	2592	1013	921	35.5	0.30
Water courses/beds	0	3	0	0	51	69	0	123	54	-32	-26.0	-0.01
Woodlands/plantations	0	2	4	8	1	4	155	174	19	714	410.3	0.23
Grand Total	3010	613	12815	3040	3513	91	888	23970				
Gross Gain	**24**	**227**	**1908**	**234**	**1934**	**22**	**733**					

Note: the diagonal shaded box indicates persistence of categories while non shaded areas show changes

Source: Derived from the LULC maps of the watershed

4.2.4. Persistence, Net change and swap of LULC in Gedalas Watershed (1973 -2017)

As noted above, post classification comparison approach was employed using overlay functions of ArcGIS environment and Excel pivot table to determine the LULC transitions between 1973 and 2017. As Table 4.4 resume, analysis of gains, losses, total change, absolute value of net change, persistence, swap, gain to persistent (g_p), loss to persistent (l_p) and net change to persistent (n_p) ratio of LULC classes were carried out between two independently classified maps of the initial and last study periods of the Watershed.

The gains are the differences between the column totals and persistence. The losses are the differences between row totals and persistence. The sum of the absolute value of gains and losses for each category gives total change. Absolute net change is the absolute value of the difference between percent of LULC categories in 1973 and in 2017 in the watershed. Swapping is the surface area exchanged between LULC categories; this corresponds to the difference between total change and net change for each category. For example, equal gains and losses between LULC categories 1 and 2 would provide a net change of 0% but could correspond to a substantial total change and high swapping if significant areas of category 1 were converted to 2 and vice versa (Teferi et al., 2013; Braimoh, 2006; Zewdie & Csaplovics, 2016; Adugna et al.; 2017).

Table 4. 4: Percent of LULC gain, loss, swap and Absolute net changes in Gedalas Watershed (1973-2017)

LULC Class	Total		Persistence	Gain	Loss	Total change	Swap	Absolute value of net change (N)
	1973	2017						
Afro/sub Alpine veg	19.77	14.66	12.46	2.2	7.31	9.52	4.4	5.12
Bare lands	2	3	1.61	0.95	0.05	1	0.1	0.9
Farmlands/ Settlements	50	53	45.5	7.96	4.68	12.63	9.36	3.27
Grasslands	16	13	11.71	0.97	4.63	5.61	1.94	3.67
Shrub/Bush lands	11	13	8.26	4.3	2.55	6.86	5.1	1.76
Water courses/beds	1	0	0.29	0.09	0.22	0.31	0.18	0.13
Woodlands/plantations	1	4	0.65	3.05	0.08	3.14	0.16	2.98

As described above, the largest persistence in the watershed is observed for farmlands/settlements (45.5%) followed by Afro/sub alpine vegetation (12.5%) and grasslands (11.7%) for the period from 1973-2017). Similarly, farmlands/settlements, shrubland and woodlands/plantations experienced relatively more gains than losses (Table 4.4). Among these, farmlands/settlements showed the largest values for gain and losses as compared to the other LULC types and experienced the largest overall change within the watershed, even though its initial surface area was the largest. It also demonstrated the highest rate of swapping, indicating extensive exchanges with other LULC types, losing surface area to other classes and gaining at the same time area from other categories. This implies, of the seven LULC types, farmlands/settlements were the most dynamic category in the watershed, experiencing the swapping change dynamic during the study period. In contrast, the highest loss was recorded in Afro/sub afro alpine vegetation followed by grasslands. The former category has also the highest value for swapping next to farmlands/settlements and grasslands during the period.

The value of net change also illustrates some differences among the areas between categories. The highest net change value was observed in Afro/sub afro alpine vegetation. During the period, its losses were quite higher than its gain. Meanwhile, grasslands, with higher loss than gain, have the second highest net change value for the period. It had the third higher value for losses in the period.

4.2.5. Persistence and vulnerability of LULC dynamics in Gedalas Watershed

The level of the ratio shows in all cases the gains to persistence ratio (indicates the chance to gain compared to their persistence), loss to persistence ratio (specify the exposure of the LULC for transition) and the net change to persistence ratio (indicates how much times the LULC types gain/loss than its persistence) (Braimoh, 2006; Teferi et al., 2013; Zewdie and Csaplovics, 2016).

If the Gain to Persistence ratio (G/P) values is higher than one indicates a greater chance of a land use/cover to gain than to persist. If the value of loss to persistence ratio (L/P) is higher than one, the LULC are rather vulnerable to changes to other LULC classes than to persistence (Braimoh, 2006; Teferi et al., 2013). In this study, G/P & L/P values of all land use/cover classes are lower than one indicating the tendency to persist rather than to loss or gain (Table 4.8). However, the G/P ratio of bare lands and Shrub/bush lands are relatively higher, implying that these LULC categories have a tendency to gain than remain persistence. This implies the probability of higher vulnerability of the watershed to degradation and abandonment of farm lands to shrub/bush lands. The G/P of Woodland/plantation is zero, signifying that the gain of woodland/plantation is insignificant compared to its persistence.

Similarly, all land use/cover classes have an L/P value of lower than one indicating a lower vulnerability to lose than to persist. However, afro/sub Alpine vegetations have higher tendency of losing to other LULC classes as compared to others (Table 4.5).

The net change to persistence ratio (N/P) of bare lands is higher indicating the net gain of bare lands increased by half of its persistence. The net loss of afro/sub Alpine vegetation is more of its persistence within the watershed. Grassland also got a net loss of about one-third of its persistence during the study period. The net change to persistence ratio is closer to zero for Farmlands/ Settlements LULC classes indicating that it had a lower tendency to change.

Table 4. 5: Gain to persistent (g_p), loss to persistent (l_p) and net change to persistent (n_p) ratio of LULC categories in Gedalas Watershed (1973-2017)

LULC class	Gain (G)	Loss (L)	Persistence (P)	G/p	L/p	N/p
Afro/sub Alpine veg	2.2	7.31	12.46	0.18	0.59	-0.41
Bare lands	0.95	0.05	1.61	0.59	0.03	0.56
Farmlands/ Settlements	7.96	4.68	45.5	0.17	0.1	0.07
Grasslands	0.97	4.63	11.71	0.08	0.4	-0.31
Shrub/bush lands	4.3	2.55	8.26	0.52	0.31	0.21
Water courses/beds	0.09	0.22	0.29	0.32	0.77	-0.45
Woodlands/plantations	3.05	0.08	0.65	0	0.13	-0.13
Total	19.53	19.53	80.47	1.87	2.33	-0.46

4.2.6. LULC patterns across Agro ecology

Assessment of LULC patterns across agro ecological units is important to understand effects of topographic units for guiding sustainable land management decisions and rehabilitation strategies. To analyze the relationship between LULC and topography, the Maps of the four study periods were delineated into three agro ecological belts considering elevations derived from 30-meter Digital Elevation Model (DEM). The results of investigation of LULC status for the years 1973, 1986, 2001 and 2017 based on altitude, are given in Figure 4.2.

Superimposing the LULC map with the agro ecology unveils that LULC classes were disproportionately distributed along with the three agro-ecological belts. The largest proportion of farmlands/settlement and grasslands are mostly located in regions within *Dega* and *Wurch* agro ecological zone of the watershed. The main reason was that the majority of the lands suitable for cultivation were located in these areas. While most of the shrub/bush lands, woodlands/plantations and bare land were located in the suburbs of the rugged terrain of *Weyna Dega* and *Dega* zones of the sub watersheds than in the upper reaches. This is due to the fact that most of the topography of the lower reaches is characterized by quite rugged terrains and therefore, enclosures are dominantly confined in this zone. Hence, areas that can be used for cultivations are very limited.

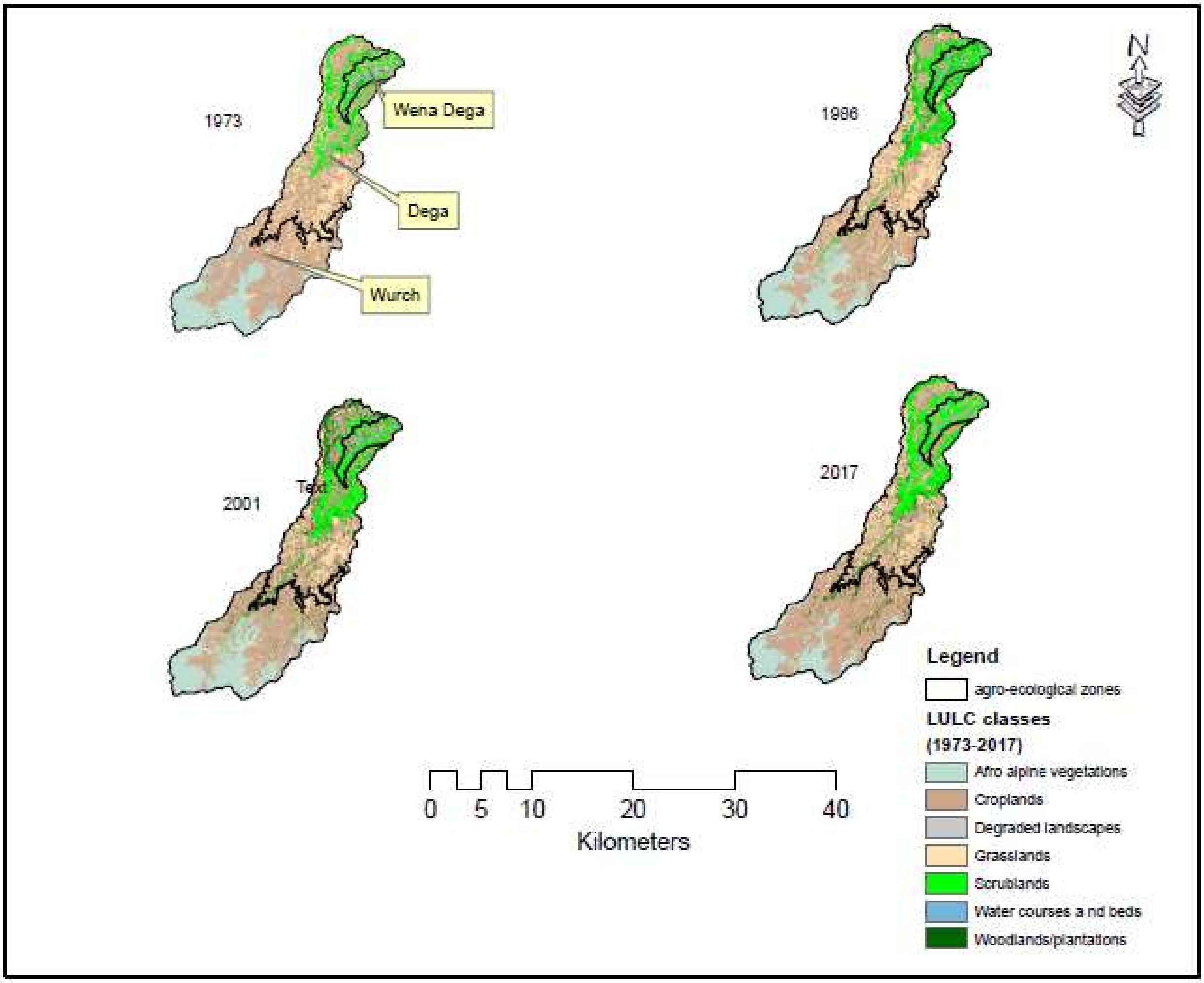

Figure 4. 2: Map Depicting Land use/cover distribution along Agro Ecology (1973 -2017)

The results further show that the farmlands/settlement and grassland areas are mostly located in areas with an altitude of above 2300 meters and extend up to above 3800 meters in the watershed. This indicates that the inhabitants of rural villages in the watershed increase with elevation despite it gradually decrease as it approaches to the highest elevations. Progressing upwards, however, there were no farmland/settlements witnessed especially above 3860meters in the watershed. Yet, in some areas, which were not used for agricultural activities in 1973, 1986 and 2001 has now turned in to cropland areas. This is probably the effects of local climate change. Expectedly, the availability of woodland/plantations class also decreased in lower and higher areas of the watershed as well. The reason for the decrease would be attributed to unfavorable climatic conditions for the survival of trees species.

Though changes experienced in all agro ecological zones, process and extent of LULC transitions vary relatively across agro ecologies. For example, the major spatial change in afro/sub afro alpine was the conversion to cropland/settlements and/or grassland in mountain region of the Wurch Agro-ecology. While the most significant change in Woodlands/plantation, grass lands and shrub/bush lands occurred within Dega agro ecological zones (Table 4.6).

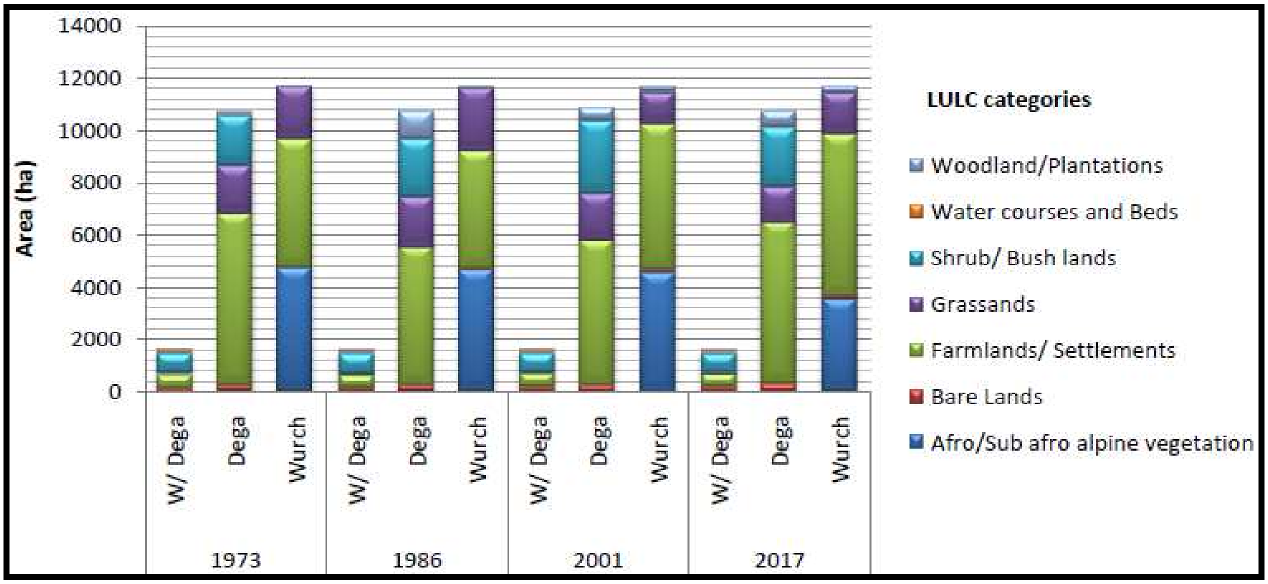

Figure 4. 3: Land use distribution along Agro Ecology

Table 4. 6: Area statistics for agro ecology based LULC classes for Gedalas watershed

Year	Agro Ecology	LULC types & Area (ha)							Total
		Afro/Sub afro alpine vegetation	Bare Lands	Farmlands/ Settlements	Grassands	Shrub/ Bush lands	Water courses and Beds	Woodland/P lantations	
1973	W/ Dega	0	137	527	118	671	98	63	1614
	Dega	13	215	6580	1835	1913	19	107	10682
	Wurch	4725	45	4922	1964	8	6	4	11674
	Total	4738	397	12029	3917	2592	123	174	23970
1986	W/ Dega	0	162	460	115	718	79	80	1614
	Dega	19	209	5300	1943	2190	11	1010	10682
	Wurch	4640	54	4480	2412	16	5	67	11674
	Total	4659	425	10240	4470	2924	95	1157	23970
2001	W/ Dega	0	168	524	107	666	83	66	1614
	Dega	7	246	5540	1766	2802	13	308	10682
	Wurch	4556	106	5537	1217	80	5	173	11674
	Total	4563	520	11601	3090	3548	101	547	23970
2017	W/ Dega	0	170	488	105	685	65	101	1614
	Dega	0	294	6157	1362	2273	15	581	10682
	Wurch	3513	149	6170	1573	52	11	206	11674
	Total	3513	613	12815	3040	3010	91	888	23970
1973-1986	W/ Dega	0	25	-67	-3	47	-19	17	0
	Dega	6	-6	-1280	108	277	-8	903	0
	Wurch	-85	9	-442	448	8	-1	63	0
	Total loss/gain	-79	28	-1789	553	332	-28	983	0
1986-2001	W/ Dega	0	6	64	-8	-52	4	-14	0
	Dega	-12	37	240	-177	612	2	-702	0
	Wurch	-84	52	1057	-1195	64	0	106	0
	Total loss/gain	-96	95	1361	-1380	624	6	-610	0
2001-2017	W/ Dega	0	2	-36	-2	19	-18	35	0
	Dega	-7	48	617	-404	-529	2	273	0
	Wurch	-1043	43	633	356	-28	6	33	0
	Total loss/gain	-1050	93	1214	-50	-538	-10	341	0
1973-2017	W/ Dega	0	33	-39	-13	14	-33	38	0
	Dega	-13	79	-423	-473	360	-4	474	0
	Wurch	-1212	104	1248	-391	44	5	202	0
	Total loss/gain	-1226	216	786	-877	418	-32	714	0
	Note: The positive sign indicate expansion in size, while the negative sign show shrinkage in area								

4.2.7. LULC Patterns along Slope Categories

Despite there were minor variations in spatial coverage, the satellite imagery analysis for the study periods revealed that more than 80% of shrub/bush lands and woodlands/plantations were situated on slope categories ranging from moderately steep to very steep slopes. This is most likely due to the fact that since these areas are not conducive for cultivation, enclosures and rehabilitation activities were/are focused on these areas. Because of the poor natural conditions and sloppy nature of the terrain, much reforestation occurred in these areas. While the largest shares of farmlands/settlements and grass lands are located from flat to strongly slopping landscapes, more than 25% of these land use categories were/are still found on steep and very steep slope categories and hence, those steep cultivated lands could suffer from accelerated soil erosion and associated loss of essential soil nutrients. From this it can be easily understand that though the federal rural land administration and land use proclamation of Ethiopia (Proc. No. 456/2005, Article 13/6) stipulates the slope classes which is more than 60 percent shall not be used for plowing and livetock grazing (FDRE, 2005), in reality almost every steep slope had already been transformed to cultivated and/or grazing lands. In fact, the Revised Amhara National Regional State Rural Land Administration and Use Proclamation (Proclamation No. 133/2006), article 5/7), allow use of these rural land having slope more than 60 percent if it was a priory used by the land holders and so long as properly managed it. Thus, in the Gedalas watershed, many areas of slopes greater than 60% are found employed for agricultural purpose, with or without conservation structures (Table 4.7). Such state of affairs accelerates the deterioration of ecologically sensitive environments and threatens the fate of sustainability of local livelihoods. Hence, calls for great attention for effective SLM activities.

Table 4. 7: LULC Types based on slope categories in Gedalas Watershed (1973-2017)

		Slope Categories						
Years	Land use/Cover Type	Flat	Sloping	Strongly sloping	Moderately steep	Steep	Very steep	Grand Total
1973	Afro/Sub afro alpine vegetation	73	271	400	1869	1889	236	4738
	Bare lands	17	47	55	142	92	44	397
	Farmlands/ Settlements	546	1495	1771	4818	3008	391	12029
	Grasslands	380	829	770	1293	506	139	3917
	Shrub/bush lands	39	113	122	640	1100	578	2592
	Water courses/ beds	34	25	26	23	13	2	123
	Woodlands/plantations	9	10	17	47	55	36	174
	Total	1098	2790	3161	8832	6663	1426	23970
		Slope Categories						
Year	Land use/Cover Type	Flat	Sloping	Strongly sloping	Moderately steep	Steep	Very steep	Grand Total
1986	Afro/Sub afro alpine vegetation	64	193	308	1787	2059	248	4659
	Bare lands	11	32	43	122	83	134	425
	Farmlands/ Settlements	513	1423	1630	4329	2181	164	10240
	Grasslands	448	999	898	1365	567	193	4470
	Shrub/bush lands	34	73	146	713	1374	584	2924
	Water courses/ beds	11	24	21	33	5	1	95
	Woodlands/plantations	17	46	115	483	394	102	1157
	Total	1098	2790	3161	8832	6663	1426	23970
		Slope Categories						
Year	Land use/Cover Type	Flat	Sloping	Strongly sloping	Moderately steep	Steep	Very steep	Grand Total
2001	Afro/Sub afro alpine vegetation	58	190	316	1839	1956	204	4563
	Bare lands	13	35	52	110	143	167	520
	Farmlands/ Settlements	620	1604	1941	4760	2467	209	11601
	Grasslands	344	719	631	905	378	113	3090
	Shrub/bush lands	47	182	161	1026	1482	650	3548
	Water courses/ beds	11	25	23	34	7	1	101
	Woodlands/plantations	5	35	37	158	230	82	547
	Total	1098	2790	3161	8832	6663	1426	23970
		Slope Categories						
Year	Land use/Cover Type	Flat	Sloping	Strongly sloping	Moderately steep	Steep	Very steep	Grand Total
2017	Afro/Sub afro alpine vegetation	69	210	301	1772	1064	97	3513
	Bare lands	35	46	68	136	147	181	613
	Farmlands/ Settlements	609	1649	1931	5165	3238	223	12815
	Grasslands	301	724	642	921	353	99	3040
	Shrub/bush lands	52	80	101	562	1482	733	3010
	Water courses/ beds	10	24	22	30	3	1	91
	Woodlands/plantations	22	57	96	246	376	91	888
	Total	1098	2790	3161	8832	6663	1425	23970
	Note: *0-5 = flat; 5-10 =sloping; 10-15= strongly slopping; 15-30 = moderetly sloping; 30--60= Steep and >60 = very steep (FAO,2006)*							

4.3. Major Drivers of LULC Change in Gedalas Watershed

Similar to LULC driving forces reported in a different place in the country (Garedew et al., 2009; Bantider et al., 2011; Abate, 2011; Fisseha et al, 2011; Abate and Lemenih, 2014; Mekasha et al., 2014; Ariti et al., 2015; Kindu et al., 2015; Zewdie&Csaplovics, 2016, Gashaw et al., 2017), it is likely that the existing LULC change in Gedalas watershed is the outcome of the cumulative effects of the interactions of natural processes and anthropogenic factors. Due to paucity of required data, this research did not determine the degree of associations between LULC changes and driving factors lying behind these changes. Therefore, what is presented below are literature-based author's selected major LULC changes driving forces and associated implications supplemented by perceptions of local residents in the watershed.

4.3.1. Geomorphological units of the watershed

The earth's surface configuration and landforms characteristics are important aspects of the watershed that influence LULC types and natural resources management. Geomorphological units are one of the main natural factors that determine vegetation cover and species diversity (Frederick et al., 1980). Geomorphology also controls the variety of human activities (i.e. land use).

As can be referred from Table 3.1 of Chapter 3, some 34 percent of the watershed area consists of steep to very steep slopes, with gradients of 30 percent or more, another 50 percent is areas with slopes of 10-30 percent. In contrast, only about 17 percent of the watershed is made up of flat to slopping areas. Given such rugged landscape, land for settlement, cultivation and grazing are extremely scarce in the watershed. With growing land paucity, many hillsides have been converted into cultivated/grazing lands for many generations. An attempt was made to conduct woody vegetation inventory based on Geomorphological units.

As expected, the results revealed that woody plant species compositions were dissimilar between agro ecological setups and close relationship between vegetation type and altitude were clearly visible. In general, lower parts of the watershed demonstrated more diversified and mainly dominated by broadleaf species the upper one (see chapter three- natural vegetation of the watershed for details). This clearly implies that different Geomorphological units influence the land cover characteristics by controlling the type of vegetation cover and species diversities. This is justified by the fact that many factors interact concurrently in relation to the variations in vegetation types (e.g., climate, altitude, soil type, etc).

4.3.2. Population pressure and associated poverty

The impact of population pressure and its associated socio-economic activities has long been recognized as one of the key driving forces of LULC changes and related environmental threats (Lambin*et al.*, 2003; Blowers *et al.*, 2008; Gebresamuel et al., 2010; Smith and Zeder,2013; Woldeyohannes et al., 2018). Studies on the Malthusian concern articulates that high population growth coupled with poverty triggers rapid human-environment interactions to satisfy increasing demands for food and biomass energy (Hurni, 1993; Whiteman et al., 2009; De Castro et al., 2012; Bewket and Abebe, 2013). According to Central Statistical Agency (CSA, 1984, 1994 & 2007) repor, the population size of Tenta Wereda (where the study watershed is part of it), has more than doubled in the last three decades, yielding proportional increase in the demand for crop and grazing lands. Since rapid population growth is happening in the face of poverty and food insecurity, it has serious implications on the resource base. Though it was very difficult to obtain an accurate demographic trend data at the watershed level, as part of the Woreda, it is possible to gain insight about the population situation of watershed from the Woreda population data.

According to our analysis of the LULC change matrix and on-site observations, there was a strong trend of the increase in cultivated/settlement lands in the watershed. As human population increases, land per capita declines and the demands for crop and grazing land increase leading destruction of forests and woodlands, expansion of cultivated and grazing lands into unfavorable topographic and more fragile ecosystems (steep slope and marginal lands) in the watershed. As the vegetation is removed and the land is intensively used for crop production, the top soil becomes more vulnerable to erosion; thus, the degraded land area has expanded. In the same way, as the vegetation is intensively removed, wood for fuel becomes scarce. This has called for, using dung cakes and crop residues as more important fuel than using them for soil enhancement. Moreover, decline of fallow periods leads to the reduction in soil fertility status and land productivity (FAO, 2007).

As noted in informal interviews with elders in the community, private and common trees were cut for fencing purpose, construction, production of charcoal and for consumption as fuel wood. As a result, grasslands are converted to croplands/settlements, especially during the last twenty years, to meet the demands of the growing population in the watershed.

Poverty and associated unsustainable livelihoods are another indirect driver facilitating LULC changes by putting undue pressure on vegetation covers. Poverty may lead to mismanagement of land resources; which accelerates the process of land degradation and associated decline in crop productivity. This, in turn, can cause further impoverishment, accelerating the vicious circle of poverty and environmental degradation. Poverty and decline in agricultural productivity tend to have a bidirectional relationship; as the poor farmers are unable to implement yield enhancing inputs (Deininger and Jin, 2006; Deininger and Burns 2011; Kirui and Mirzabaev, 2014).

In spite of rapid economic growth and stepping up government's policy efforts to deduce poverty for the last few years in Ethiopia, the national poverty rates have not changed as expected (World Bank, 2014). Poverty is widespread among rural communities of the study watershed probably due to scarcity of fertile land, recurrent drought, inadequate government support and insufficient market for the agriculture outputs. Many farmers of the watershed do not achieve food security and depend on food relief. Poverty may also contribute to LULC changes in rural areas by stimulating environmental protection policy responses and practices Lambin et al., 2001; Lambin et al., 2003). For instance, though it was not still adequately addressing the environmental problems, it was partly against drought induced widespread rural poverty and environmental degradation that Ethiopian government stipulate environmental protection and rehabilitation ideas and strategies since the 1970s.

Likewise, energy use is another critical factor in LULC changes as is evident from farmers clearing vegetation/trees from their farms or nearby woodlands/shrubs for home consumption and to sell as firewood or charcoal to the nearby urban resident.

4.3.3. Rising demand for agricultural lands

Demand for agricultural lands has been the greatest driving force of LULC transformation (Zeleke & Hurni, 2001). As elsewhere in rural Ethiopia, the lion's share of the population of the study watershed depends on agriculture as their main source of income. However, lack of agricultural inputs, shortage of cultivated and grazing lands, infertile soil and the reliance on seasonal rain fed agriculture makes agricultural production unreliable to support rural livelihood. Thus, to increase crop yield and income, people have been cultivating marginal lands and steep slopes. This has indeed contributed to increasing LULC changes in rural landscape (MEA, 2005).

Local residents were asked to give their view about vegetation status, farmland sizes and soil fertility over time. Their responses are summarized as follows:

> *The situation of vegetation during the 1970s was better than the present despite recurrent drought impacts. Formerly, the human population was relatively small and agricultural lands were not a scarce resource. Consequently, there was a reasonable fallow period and hence, crop productivity was relatively better. There was also no problem for fire wood and livestock feed, the soil had a better fertility status and the rainy months were long. But, nowadays woody vegetation and variety of tree species, which were predominant in the area were steadily disappears and at present no longer visible or are available in limited amounts and area coverage; unlike the past, steep slopes are currently under cultivation. The fertility of the farm land has exhausted and its productivity has declining. It is demanding much input, which was not the case in the past.*

The interview result showed that local community experience was different from the result of Satellite image analysis result of woody vegetation. This contradiction is probably due to the fact that local communities' explanations may refer to scattered trees available in the time. From the above conversation it seems the assumption "more people, more crop land" held true in the Gedalas watershed.

4.3.4. Use of Biomass for fuel energy and incidence of bush fire

It is generally accepted that most of human food and heating require source of energy to be processed in any form (Kees & Feldmann, 2011). In developing countries like Ethiopia biomass such as firewood, charcoal, crop residues and animal dung are the major sources of fuel for domestic uses (Kees & Feldmann, 2011). A socio-economic survey on the trends and impact of production and use of biomass energy was undertaken in study watershed. As the study result reveals, lack of cheaper alternative sources of energy, force local communities to totally depend on biomass energy (fuel wood, leaf litter, crop residues, and dung cakes) to meet their household energy needs (e.g. cooking, boiling, lighting, and heating) in all agro-ecological setting of the watershed. However, the inefficient production of firewodd poses a challenge on the sustainability of the environment. Though it was not pervasive, selling of charcoal and bundles of firewood were witnessed in the local market. Most of charcoal was generated from Weyna Dega areas of the watershed where there was alternative tree species conducive for charcoal making. Though kerosene is also employed as energy sources by the inhabitants for night time lighting, the majority of households use wood as a source of heat and light for night. Currently there are limited alternative energy sources (such as solar energies); however, the majority of households are unable to satisfy their energy requirements with these alternative energy sources partially for reasons of inaccessibility and unaffordable prices. Due to this fact, the majority of residents depend on biomass energy sources. The household survey and the focus group discussions confirm that the bulk of households in the study area consume 10 to 15 bundles (human load) of firewood per month for lighting, heating and cooking purpose.

However, due to faster utilization than natural regeneration of capacity of trees, the supply fuel wood as source of energy is steadily failing in most parts of the watershed. Moreover, there is very little private investment in plantation of tree to compensate consumption. As pointed out by the community, the vegetation cover of the area has been highly depleted in the last few decades and currently people are travelling longer distances and spend more time in collecting fuel wood as the most preferred tree species (that burn well and produce less smoke) for fuel wood is getting scarce.

As one elderly woman informant from Weyna Dega area provides the following clear evidence:

> *Formerly dried fuel wood collected from both public and private land was enough to individual fuel wood needs. Poles for home construction and grass for thatching were not a problem. But nowadays all these are not easily available and remain unsatisfactory to meet the needs of the majority of local community. In effect young living trees are cut to produce fuel wood.*

The community perception was complemented by a plant inventory in the remnant woodlands in all sub-watersheds. Plant inventory was undertaken in the relatively undisturbed and disturbed woodlots. In the relatively undisturbed woodlots, there were many species of old trees, saplings, seedlings, and stumps and found in religious compounds, tomb sites and in inaccessible areas while the species composition and density of vegetation in the disturbed woodlots (mostly found in accessible areas) is very low. This implies that the.

Thus, the results highlighted that the trees harvesting for biomass energy and other uses have affected the species composition and diversity in the remnant woodlots, and hence, is most likely among the drivers of LULC changes in the watershed. In agreement with this study, Abate and Lemenih (2014) reported excessive use of fuel wood and expansion of cultivated lands as the major drivers of LULC changes in northwestern Ehiopia.

In fact, it could be argued at this juncture that rural households of the study area are faced with an impossible dilemma i.e. to cook with biomass energy or not to eat a cooked meal. Hence, despite Ethiopia is currently exploring different options to meet a growing demand for energy, the authors believed that the demand for such biomass energy will not be easily replaced completely in the short term and will continue to be the primary energy sources for many households in this rural area. Therefore, the study suggests that there is a need for encouraging households to plant preferred multipurpose tree species, strengthening reforestation programs, introducing agro-forestry practices and improving sustainable woodlands management efforts along with awareness rising and capacity building of the local community on efficient use of energy saving devices.

In addition, as it was noted during field observation, infrastructure such as opening of new feeder roads not only provided access but also lowers the cost of migration and catalyzes the cutting of eucalyptus trees for logs, fuel wood, timber and a host of other useful products which in turn reduce the tree cover of the hillsides of the watershed. Although it is still relatively rare, periodic fire, particularly during the dry seasons, arise in bush/shrub covers which can have significant negative impacts on vegetation cover and plant species composition of the landscape in the watershed.

Figure 4. 4: Deforestation of Eucalyptus Woodlots (left), woods prepared for shipment (middle) & bush fires on the landscape (right) (photo: author, 2017)

It appears, however, a paradox that on one hand the opening of road networks facilitates rate of deforestation and on the other hand it accelerates socioeconomic development by facilitating on time delivery of agricultural inputs, market access for products, to offer food aid during drought years and even to support and follow up environmental rehabilitation activities and other social services of the *Kebele* by the Woreda respective institutions.

4.3.5. Livestock pressure

Livestock in the study watershed are extremely important as they have multifaceted roles, such as a source of food and as a means of security at times of crop failure and so on (see chapter 3 for details). At the same time, there is no doubt that the environmental burden that comes with the livestock production is also significant. Over utilization of natural vegetation by domestic animals has brought about changes in vegetation structure and composition. These changes have caused degradation of the woody vegetation cover with concomitant soil erosion problems (Moges and Holden, 2006; Tefera and Sterk, 2010). Heavy grazing increases soil erosion not only by destroying of vegetation cover and leaving the soil bare but also by trampling and compacting the soil which reduces soil porosity, infiltration capacity and, hence, increases the amount and intensity of runoff and sediment production (Pineiro et al., 2010). The enhanced action of animal hooves on limited grazing land damages the surface soil and gradually develops into rills and then gullies, exacerbating soil erosion. All these issues reflect how increasing livestock pressure adversely affected the carrying and productive capacity of the land and cause LULC change and subsequent land degradation.

In the study watershed, subsistence-oriented mixed crop-livestock farming system is commonly practiced in all parts of the watershed. However, animal feed has becoming the most critical challenge for livestock development. High human population density and large number of livestock, along with rugged surface features of land and erratic rainfall, exacerbate the problem of livestock management. In the watershed, grazing land is either privately owned or commonly used among the community members. Most of the communal grazing land was/is found on hill slopes. Free gazing is commonly practiced in all reaches of the watershed.

In the lower reach of the watershed (Woinadega area), it is common to use chopped up branches and barks of acacia trees for cattle fodder especially during dry seasons. Hence, adds pressure on fate of sustainability of these tree species in the area.

Figure 4. 5: Farmers chopping branchs of acacia arabica tree for livestock feed (Phot: author, 2018)

The local people claim that the quality of pasture in the grazing area and the abundance of preferred forage species in their locality have deteriorated over time due to grazing pressure. It is worth to citing the assertion of one key informant's response from the Wurch zone of the watershed as follows:

> *At the beginning of the 1970s, many people had a large quantity of livestock (including cattle, pack animals and sheep) as there were abundant grazing lands. But, nowadays, areas which were communal grazing sites in the past are either delineated for closure or converted to croplands. Free grazing is legally prohibited though some individuals are not willing to implement in practice. Since the available grazing lands are not sufficient, sometimes we complement it by purchasing straw and grass from distant areas. Hence, the number and variety of livestock population gradually decline as the result of lack of grazing lands and water resources". Similarly, another informant from the same area has added recurrent droughts, animal disease and scarcity of labor to look after the animals (particularly for ruminants) are among the cause for livestock reduction in the watershed.*

It is clear that livestock pressure initiates LULC change by causing removal of vegetation cover beyond the point of recovery.

4.3.6. Climate change and variability

Though human populations are blamed for accelerated LULC transformations, there is also a great deal of consensus that LULC can be altered by such natural events as the rapidly changing world climate and other naturally derivative ecosystem dynamics. There are strong association between LULC change and climate change (Stringer et al., 2009). Evidently, climate change provokes LULC change and poses a threat to environmental sustainability and natural resource conservation (Jones et al., 2009; Oliver and Morecroft, 2014). Climate change and variability are induced the occurrences of extreme weather events such as drought. Recurrent drought causes vegetation cover changes in the landscapes resulting in raises in watershed degradation and modification and/or alteration of plant species density and diversity (Ringrose et al., 2002).

Ethiopia is arguably the most liable country for the impacts of climate change and variability (Kassie et al., 2014). Among climate related catastrophes, drought[8] and irregularities in seasonal rainfall amount and distributions are the major ones that causes widespread destruction of the natural vegetation (Deressa, 2007; Jewitt et al., 2015). Historical evidence shows that, the northern part of the country, including the study area, had been subject to sporadic drought, which led to the destruction of the vegetation covers. For example, the famine of Wollo caused by drought of 1984/85 is still remains as tragic memory to the world community.

The following quote taken from the review of Rahmato is a good proof for the above explanation:

> *The Wollo (where the study area is part of it) highlands are on the leeward side of the main rain-bearing winds and thus receive much less precipitation than the highlands in western Ethiopia on the same latitude. Rainfall is frequently unreliable, and on many occasions the belg rains may fail completely, and the Kiremit rains may be short. This has been the process by which droughts and famines have been triggered for countless generations (Rahmato, 2001:6)*

Drought can directly influence LULC through its effect on spatial differences of the natural vegetation types and agricultural crops (Cook and Sims, 1975). Drought can also indirectly affect LULC through changes to socioeconomic systems by causing crop failure, loss of livestock, and degradation of pasture lands; which in turn forced local communities to overexploit vegetation resources as alternative means of survival through selling of fire wood and charcoals (Olesen and Bindi, 2002; Abate and Angassa, 2016). This risk management strategy, in turn, has reflective effects on LULC changes. In addition, climate change still influences LULC positively by instigating policy responses and programs. In this regard, it is reasonable to mention the United Nations Collaborative REDD + Programme, which was adopted to conserve forests resources and enhance forest carbon stocks by supporting developing countries in the areas of policy development and strengthening national institutions (Oliver and Morecroft, 2014). The government of Ethiopia has recognized its importance and became an official member of the UN-REDD+ program since June 2011 and institutionalized the Programme (Bekele et al., 2015).

This implies that the government of Ethiopia seems to be more dedicated to deal with the climate change challenges associated with the problems of deforestation and forest degradation (Bekele et al., 2015). In

[8] Drought is a complex phenomenon, but in this study, drought is considered as a period when the precipitation is lower than long-term averages.

this context, the country has dopted strategies to build a climate resilient green economy (FDRE 2011a). Moreover, the country is undertaking several nationally appropriate mitigation actions including afforestation and reforestation programs, rehabilitation of degraded lands and watershed management activities, livelihoods improvements, among others, to mitigate the adverse effects of climate change (Bekele et al., 2015). This policy response contributes to the LULC change of the country in general the study area in particular.

As part of northern Ethiopia, Gedalas Watershed has been experiencing drought episodes in the last decades. The communities' perceptions about shock/events associated with the drought were investigated for the study periods. There was particular consensus on the devastating effects of this drought's incident by almost the entire communities living in the watershed. However, people living on the cold upper reach of the watershed recalled the drought events bitterly as compared to the others. This is probably due to the fact this part of the watershed is more depend on "belg" rains. When the "*belg*" rain fails, their chance of growing Barley is already lost. But for the other parts of the watershed, they have the second chance of using "*Kiremt*" rain.

An attempt was made to investigate the views of local communities related to drought incidence and other climate related issues over time in their locality. Virtually all the respondents perceived the increase in drought incidence as one of the indicators of climate change and variability.

Table 4. 8: Perceptions on indicators of climate Variability by the local communities **(N=384)**

Perceptions on local indicators of climate variability	SA (Nx5)	A (Nx4)	NS (Nx3)	DA (Nx2)	SD (Nx1)	Total weighted Score (X*)	weighted Mean(X/N)	Score as % of the max (X/N)/5*100	contribution in %	Rank
Drought incidence becomes more frequent	1700	124	27	4	2	1857	4.84	96.72	12.06	2
Flood occurrence have increased	1005	380	150	60	8	1603	4.17	83.49	10.39	6
local temperature is increasing	1425	220	102	6	7	1760	4.58	91.67	11.41	4
Pests and crop diseases have increased	735	512	165	52	28	1492	3.89	77.71	9.69	8
Rainfall amount is decreasing	1450	340	27	0	0	1817	4.73	94.64	11.78	3
Rainfall becomes more unpredictable	1760	100	21	0	0	1881	4.9	97.97	12.21	1
water resources are decreasing and drying	1455	180	63	30	12	1740	4.53	90.63	11.29	5
Wetlands are declining	875	408	123	64	34	1504	3.92	78.33	9.77	7
Incidence of morning dew	490	408	312	124	18	1352	3.52	70.42	8.77	9
snow covered areas are still visible	0	0	15	24	367	406	1.06	21.15	2.64	10

Note: Strongly agree = SA; Agree = A; Not sure = NS; Disagree = D; strongly disagree = SD
X* = SA+A+NS+D+SD

The findings (Table 4.8) suggest that there is an increasing understanding among local communities about climatic conditions and environmental variability in their locality. As can be seen from table, the largest proportion of surveyed households perceived the unpredictable nature of rainfall and increase in drought incidence as one of the indicators of climate variability in their respective areas. The study further revealed that due to the recurrent incident of drought, water flow and wetland resources have been declining. Drought incidence was also reported not only to cause crop failure but also but they also have resulted in causing a decline in vegetation cover and emergence of pests and crop diseases that was not common before.

Results from focus group discussions and interviews concurred that in recent years, frequency and intensity of drought occurrence have increased especially since the 1970s which result in continual crop failures and food shortages at the household level. One of the 76 aged key informants residing in the Wurch area (upper reach) elaborated the climate variability of the area as follows:

> *When I was a child, we used to grow crops and the harvest was much higher compared to the present. The rain used to come regularly and consistently, and we were able to plant and harvest on time. But, since 1970s, the rainy mounths donot follow normal trends of planting seasons. The rain has become quite erratic and insufficient. Sometimes it rains and sometimes it doesn't. With no exaggeration, the amount of rainfall was not sufficient as it was before. I remember, the years 1972, 1978, 1984, 1989, 19993, 2003, 2009, and 2010 were drought years in this area. Of these drought years, the 1984 was the most terrible ever remembered in my life (Hassen Ayele, 76, Gaya).*

Most of the time long dry spell occurred at the age of crop maturity and reduced crop production. There was also an expected and needless rainfall occurrence during the harvesting period which affects the quality of the products (Local elders, as well as in focus group discussions).

Another focus group participant residing in the Wurch area of the watershed revealed that rainfall deviates from its actual time either it ends early or comes late. This enforced farmers to shift from sowing historically dominant crops of barley (*Hordeumvulgare*) toAvana (locally known as *Engido/sinar*) which was not so far widely cultivated in the Wurch agroecology of the watershed. As the respondents further revealed rainfall variability, drought, crop disease, and land degradations were the major cause for such land use change.

Similarly, focus group discussants from all survey sites revealed that pulses (locally known as "*Deballa*") like Bean (*Viciafaba*), Peas (*Pisumsativum*), vetch (*Vicia sativa*) and lentil (*Lens culinaris*) which were historically widely grown in almost all agro ecological belt of the watershed, are no longer cultivated today. Such valuable crops were the main source of protein diet and play significant role in soil fertility restoration through crop rotation. Farmers were further asked to explain their perceived reasons that constrained the production of these crops. The lion's share of respondents shared the views that in recent years they have noticed the gall like structure on the roots of these crops, what the local people named it as '*Kitign*" which means syphilis. Though it needs further study, the problem probably could be what the scientific community call faba bean gall disease. As the result, the production of such cropland has deteriorated from time to time over the years to the extent of vanishing. Since households' can no longer enjoy the nutritional benefits from of pulses, they expressed the paucity in idiomatic poem using the local language as:

"Gomen Adrgilign ke enjeraye lay
Beshroma Meblat Kerto Yelemoy"

Which roughly means since the majority of pulses used for preparing "*shiro*" (homogeneous stew prepared from powdered Bean& Pea) disappears; there is no chance to prepare it. Hence, you can give me the "*Enjera*[9]" with "*Gomen*" (Cabage, *Collard greens*). These views suggest that most farmers recognize and negatively feel the loss of such crops on their livelihoods. In fact, these events have a multi-faceted impact not only on farmers' livelihoods but also on agro biodiversity (i.e. the varieties of crops grown). Loss of this genetic variety of agricultural crops may in turn have significant implications on the biochemical cycles, recycling of nutrients, erosion combating and watershed protection, soil enriching, water flow regulation etc (UNEP, 2014).

Another informant residing in *Dega* agro ecology has pointed out that the land is not as productive as before. Compared with the past, respondent further explained that the land is not effectively growing many of the crops and many years have passed now since we had sufficient harvest. Even if crop grows, it sometimes will die either at the seedling or flowering stage. In the past farming was done without any additional manure or fertilizers. The widely held assumption among farmers is that since the land is getting old and old as the human being, it cannot grow crops as expected. An attempt was made to investigate the perceptions regarding the reasons and its consequences to their livelihoods.

In farmers' word, the land is already infected with unusual plant species what they call it "*land aids*". The land where such plant is visible, do not grow crops normally. Most of the respondents reported that such plant species were not familiar in their localities and it appears in the recent past (in fact, they do not exactly remember the years they witnessed). As they further explained such unfamiliar plant is characterized by rapid propagation and increasing coverage in time and space. Although its name & nature

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[9]*Injera is spongy pancake-like flatbread made from fermented teff, Barely or/and other crops*

needs further verification, the authors confirm during the field observation, it seems a kind of grass species with long root systems (up to 3-meter depth). In this regard, scientific communities believe that land degradation and changes in climate create favorable environments for the emergence and spread of invasive species on agriculture and other LULC classes (Turner et al., 2007).

The validity of the community perspectives, particularly of drought year was compared with the analytical results of meteorological data for the same time period (chapter three figures). The analysis result reveals that Gedalas watershed was characterized by high inter annual rainfall variability and a series of meteorological drought years. This discloses that the local perceptions on drought events were generally in tandem with meteorological data results. The findings showed that while community perceptions may be socially constructed, they could be good sources of location specific climate related information that relate to scientific data specially in areas where there is paucity of climate data.

4.3.7. Natural Resources Policy and institutional changes

The nature of government policy and land management strategies often influence land management that ultimately affects LULC status. It is a well-known fact that misdirected natural resources protection policies and poor enforcement of these policies by institutions has resulted in extensive destruction of natural resources bases (Zeleke, 2000). For example, policies and governance that do not encouraged the collaborations of local community in conserving natural resources (e.g. vegetation covers) end up being ineffective.

Similarly, land tenure polices, which refer to the rights and obligations that land users and owners have in relation to land and related resources, determine land resource management (Boef et al., 1993; Lanckriet et al., 2014; Bekele et al., 2015) and thus is often implicated as a chief driver of LULC change. Land tenure insecurity may compel land users to over exploit their land resources as they think in terms of short term gains on the land regardless of the consequences, and hence, may not be willing to protect trees and other resources which bring about remarkable impacts on its LUCC status (Wannasai*et al.*, 2008).

The tenure systems of Ethiopia underwent significant changes in the different political era (Bekele et al., 2015). Before 1974, the tenure structure of Ethiopia in general and the study area in particular was quite diversified (Rahmato, 1984; Yigremew, 2002). During the imperial regime, private ownership of land was possible and land tenure rights were secured to the nobility and local chiefs (Hoben, 1973; Rahmato, 1984). The responses of key informant farmers residing at various sites of the watershed indicated that there were various social classes pertaining to land tenure including *Yezemach / Nechelebahes Meret* (land of white uniformed soldiers), land which was granted to individuals who went to fight against foreign invasion; Galla *meret* (land of the state), land of the government but granted to individuals who provided various government services & *yechisegna meret* (land of ordinary tax payer peasants). According to local informants there was also religious related land such as *Samon* land (land of the church), and *Wofq* land (land of *the* mosque).

In general, land access during the imperial regime was based on the will of the local governors and the intimacy of individuals to the local authorities. In this context, local chiefs (locally known as *Balabats*) were on the top social class of the community, and hence possessed large areas of land while *Chisegna* which includes such social groups as farmers, blacksmiths, merchants, weavers, potters, tanners, etc could get accessed to land to build houses and their land was confined in most cases on steep slope hillsides and on mountain edges, which were characterized by high erosion and low soil fertility status. This brought land tenure insecurity among farmers which in turn has had impact on the long-term land management investments (Teka et al., 2013).

After the overthrow of the monarchy and its ascent to power, the Derg (The military junta) enacted the Rural Lands Proclamation on 31/1975; nationalize all rural land from the landlords and redistributed it to the tillers of the land. The proclamation also insisted on the establishment of a peasant association (Rahmato, 1993; Getachew, 2005). However, it was argued that, using the institutional vacuum as an opportunity, large areas of the remaining forest and shrub lands were destroyed by people until the establishment of formal local governments. However, after the formulation policies and establishment of peasant association, environmental protection agenda was given more emphasis. As elsewhere in the northern part of the country, the Derg government was popular in the study area for the implementation of environmental rehabilitation program through tree-planting campaign, hillside closure, soil and water conservation activities and application of resettlement program for vulnerable populations (reallocation of farmers residing on steep slopes to other places), to mention but a few.

Despite the Derg's land reform was initially acknowledged as radical, periodic land redistribution was common practice, which exacerbated tenure insecurity which led to loss of incentives for sustainable land management and tree planting among farmers (Yigremew, 2002; Rahmato, 2009).

In addition to this, the farm land fragmentation and scattered settlement patterns were believed to have slowed down the progress of rural sector and underscored the importance of the establishment of cooperative alongside resettlement and villagization schemes. Among these, the formation of Peasant Producers' Cooperatives in the last years of Derg was the major challenge for the farmers in the watershed its surrounding, which facilitated seize of the best and fertile land and other precious resources, such as water points and grazing lands by members, evicted many non-member farmers and consequently, the displaced farmers moved to the marginal lands and steep slope area and engaged in the conversion of significant amounts of shrub and bush lands to agricultural lands that has contributions to changes in the LULC patterns in the watershed.

Such action of the Derg was not acknowledged by the majority of the population in the area and farmers eventually openly oppose the authorities of the government and provide unreserved support for the EPRDF forces that was fighting against the Derg regime (Gebreyesus, 2012).

Under the current government, the federal constitution vest land ownership in the state and the public (***FDRE, 1995, Art. 40/3)*** though the land redistribution is stipulated in rural land use documents as deemed necessary***.*** Land users have only usufruct rights. Land selling and buying is not possible. In fact, the land issue is still one of the most debatable topics among scholars. There two contemporary contending views on land tenure policy of Ethiopia. These are: those which favor state ownership, and those which favor private ownership of land. The former, which is supported by government, claimed that state ownership of land confirms social impartiality, provides tenure security and helps the government to set aside land for public use. On the other hand, critics defend that the state ownership of land and other resources undermines tenure security, discourages farmers' sense of ownership and willingness to invest on their farmlands and plant trees (Yigremew, 2001; Deininger and Jin, 2006; Samuel, 2006; Crewett et al., 2008; Deininger et al., 2009; USAID, 2016). The government has still inflexible stand on the state ownership of land. It seems to these historical trends that Rahmato (2001:9) wrote, "*The worst enemy of environmental protection programs in Ethiopia was not peasant agriculture, nor population pressure, but the government itself*'.

Equally important, some government strategies may induce LULC change in the country. For instance, the recently adopted Climate-Resilient Green Economy (CRGE) strategy, which aims to control deforestation and decrease emissions of greenhouse gas as the result of forest degradation of, will have its own implication on LULC status in the country.

4.4. Local Perceptions on the drivers of LULC dynamics in the Watershed

The analysis of community perceptions has gained popularity as a starting point in the context of resources management as local inhabitants possess far-reaching knowledge about their resource situations and problems. In other words, the use of geographic space is influenced by human perceptions and values (Cresswell, 2005; Callicott*et al*, 2006). Lack of information about farmers understanding, preferences and priorities constrains planning of targeted land management strategies (Crossland et al., 2018). Hence, for acceptable, effective and sustainable interventions such as for environmental management decisions, capacity building, awareness raising campaigns and public participation, exploring the local knowledge and perceptions is indispensable. With this premise, an attempt was made to assess the perceptions of local communities on drivers of LULC dynamics in the watershed. The results of the analysis demonstrated that the majority of the respondents asserted recurrent drought, population pressure and lack of livelihood options, fuel wood and timber extraction, livestock pressure and overgrazing, expansion of farmlands and settlements, government natural resources policy, terrain features of the area and land tenure insecurity (**Fig 4.6**) were perceived and listed as the major causes behind the LULC change in the watershed. The respondents were further asked to rank these driving force based on their perceived degree of intensity. Majority of the respondents (98%) ranked drought as the major driving force behind LULC change followed by population pressure and associated indiscriminate cutting of trees for fuel wood consumption.

In additions, a series of formal and informal group discussions were held with group of community members in various villages as well as key informant interviews in the watershed to identify the major perceived driving forces of LULC changes on their environment that were observed for the last 40 or so years. Key informants were elderly members of the community with an average age of 60 years and so who had lived in the study area throughout their lives and were knowledgeable about the dynamics in LULC.

. They were asked to rate the driving forces of LULC dynamics in line with the three regimes. Accordingly, they explained that during imperial regimes farmers' motivation for tree planting was relatively low. During the military regime, enclosure supplemented with enrichment plantings of local and/or exotic species as well as SWC measures were common and hence, it was relatively better. But when the current government comes to power tree cutting was escalated particularly at the transition periods. Currently, the status of land cover of the watershed is relatively better due to the ongoing sustainable land/watershed management. The discussion result was link well with the result of satellite image analysis. However, the driving forces varied widely across the watershed. In this context, it is clearly visible from the transect walk that sustainable land/watershed management program has benefited the upper parts far more than the lower reach of the watershed.

In addition, the focus group discussants frequently point out birds, monkey, and rodents (mole rats) as the potential drivers of LULC changes in Weyna Dega and Dega agro ecologies of the watershed. In the words of one of the male focus group member, *''Monkey roaming around our area not only destroys our crops during the cropping seasons but also devastate grass and other seedlings from enclosures, hillsides and grazing lands'' (Yaregal Mekonnon, 39, Delgo)*. The respondents further explained that the rate of crop attack increased before the crops have fully germinated and when it matures. Author's observation also confirms the fact that the struggle between man and monkey has been an old-aged problem in almost all parts of the watershed that damage crops and other vegetation covers, including grass. When agricultural land expands against woodlands and shrub/bush land, the monkey habitation faces problems. When natural food is in short supply monkeys raiding crop on fields, which results in man-monkey conflicts. As the result of these facts farmers forced either to abandon the land or sow crops which are not preferred by monkey like Fenugreek (*Trigonellafoenum-grecum*). This land use change exerts negative implications on the sustainability of local livelihoods and environment and hence might be one possible reason for the LULC change in the area.

Therefore, though perceptions of people are often relative, it was found out that farmers are aware of LULC dynamics in their environment which compares well with the results of satellite image. Therefore, it is apparent that documenting local community viewpoints can be used as a chief source of supplementary LULC information in developing appropriate management planning at the local level.

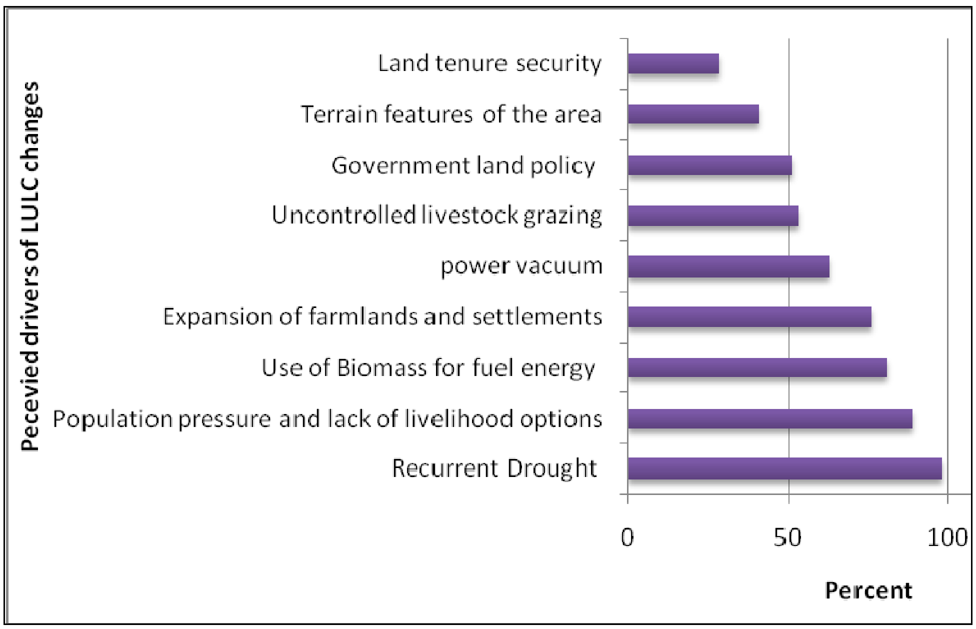


Figure 4. 6: **Drivers of LULC change ranking by the local communities (2017)**

4.5. Implications of LULC dynamics for resource degradation and the need for SLM Planning

LULC change may entail unintended implications and far-reaching long-term effects on ecological processes that potentially compromise the basic functioning of ecosystems. Therefore, understanding the implication of the past and present patterns of human-environment interaction is increasingly imperative for SLM planning (Turner et al., 2007). Changes in LULC are an inevitable and complex phenomenon with multifaceted socioeconomic and biophysical implications. The available global literature indicate that these implications could be positive (convey desirable changes) such as regaining of natural cover and rehabilitation of degraded land through afforestation, reforestation enclosures and negative (bring undesirable changes), for instance, loss of biodiversity, soil erosion, the expansion of degraded landscapes and other ecological disasters.

4.5.1. Implications on biodiversity and habitat loss

Land use/cover and habitat losses are widely recognized as the main drivers of biodiversity depletion in the world. These losses and changes are significant barriers to achieve biodiversity conservation goals and targets (MEA, 2005; Verburg, 2011; Jewitt et al, 2015). The changes in LULC also result in fragmentation of the landscape which, in turn, leads to the loss of biodiversity as well as change in the structure and function of ecosystem services provision and human dependencies.

Apart from the satellite image analysis an aged local communities residing in the watershed were asked to narrate their observation and/or what they heard about the LULC changes and associated impacts in their locality through timelines (i.e., in the last three successive regimes-Haile Silase I, Derge and EPRDF). As living witness of the area, respondents indicated what has happened in their locality in the last four decades. According to the majority of the respondents, in the past, there were dense forests and coarse grasses along with multitude of indigenous tree species in the area. But, now days, the majority of these tree species were totally or partially disappearing due to expansion of cultivated lands over time despite there is a promising signal of recovering of woody vegetations in the past two/three years. Loss of this vegetation was also allied with loss of wildlife habitat, habitat fragmentation and concomitant reduction in wildlife species diversity and availability.

The following quote regarding the loss of vegetation cover were taken from the explanation of one of the key informants residing in the *Weyna Dega* area of the watershed:

> *In the past, most of the area in our locality was covered with vegetation of various tree species. There was variety of wildlife living inside. We prepared local traditional medicine easily from leaf, roots or barks of these plant species to heal almost all kind of illness including toothache, headache, stomachache, diarrhea, influenza, skin diseases, snake bite to mention but a few. However, nowadays as you can see (pointing me to the hillside) such plant species are gradually disappearing and becomes rare (Mekonnon, 69, Sengolla).*

This implies that tapping local knowledge in the assessment of resource degradation is essential. Similarly, the alpine zone of the watershed was, historically, covered in natural grass and shrub lands. However, these areas were gradually affected by the changing climate along with the encroachment of cultivated lands to attain food security and economic aspirations of the local communities. The physical exposure of these natural ecosystems, in turn, strongly influenced the natural resources base of the watershed in general and the availability of biodiversity of the alpine zone in particular. These changes reflect human induced (amplified by climate change) LULC changes and associated loss of biodiversity in the study area. Therefore, to reverse the tides, participatory integrated watershed management practices has to be strengthening and alternative means of livelihood options for the poor have to be designed and implemented in the watershed.

4.5.2. Implication on hydrological regimes

Since the hydrological response in a given watershed is partly dependents on LULC characteristics of the area, change in LULC alters the hydrological fluxes such as runoff response and sediment load relationships of the local watershed (Mengistu, 2009; Mueller et al., 2009; Gebresamuel et al., 2010; Getachew and Melesse, 2013; Wagesho, 2014; Tesfaye et al., 2017). Empirical investigations have confirmed that LULC changes also exert influence on the energy balance within the hydrologic cycle due to their effect on evaporation, transpiration and solar radiation interception (Ma et al., 2009). Land with no or under low vegetative cover is subject to low water retention and infiltration, high surface runoff and subsequent increases in sediment and nutrient loading into streams (Woldeamlak, 2003; Alemayehu et al., 2009). Along this line, it is worth mentioning Lake Haramaya of eastern Ethiopia which vanished, due to clearing of vegetation covers for farming activities on its surrounding watershed (Alemayehu et al., 2007; Mohammed, 2009).

Interview participants from the local communities explained that the hydrological impact of LULC changes by comparing the current water status of the watershed with that of some years ago. For example, a 87 years old person living in Sengolla *Kebele* gave details about the situation as follows:

> *Some decades ago, water was not as a problem as today. Water was flowing throughout the year with in the streams. In main rainy seasons, rivers did not flow out of their banks as they do today. In recent decades, rivers become full just after peak rains and carrying more sediment which makes the water more turbid during the main rainy seasons, while in the dry seasons discharge and volume of water in the rivers drastically and, in some cases, entirely dried".*

All these indicate, LULC dynamics has direct implications on the hydrological regime and magnitude of runoff and base flow in the watershed. This reasonably calls for the need for more effort on stabilization of the land use/ cover change in general and investments on sustainable land management activities in particular so as to regulate the hydrologic related turmoil occurring in the watershed.

4.5.3. Implications on soil erosion and sediment loads

Land use/cover is one of the major factors that determine the surface runoff, rate of soil erosion and sediment yield from the catchments (Wishmeier and Smith 1978; Bewuket, 2003; Schutt et al., 2006; Schutt and Wenclawiak, 2010; Kidane and Alemu, 2015; Tesfaye et al., 2017). Removal and conversion of natural vegetation cover into cultivated land and/or grazing fields are commonly practiced in the study watershed.

Depletion of these vegetation covers then reduces protection cover of the soil and leaves the top soil vulnerable to the impacts of rain drops. This may accelerate the detachment, removal, and transport of sediment by running water, which in turn, contributes to land degradation and dramatic declines in land productivity (Woldeamlak, 2003; Tsehaye and Mohammed 2013). In contrast, the slight increase in woodlands/plantations cover had its own contribution to increasing surface detention, infiltration and retarding overland flow thereby reducing frequency and severity of floods and soil erosion hazards (Morgan, 2009).

The quantitative interpretation of satellite image and ground survey indicated that the watershed has undergone considerable LULC changes, since 1973. These LULC change along with the steep slope topography of the watershed, exacerbates soil erosion. This is particularly more intense on farmlands. As it was reported by Hurni et al. (2005), runoff and associated soil erosion is by far higher in agricultural lands as compared to forest lands in Ethiopian highlands where slopping lands are cultivated, in many cases without application of protective measures. Above all, most of the available trees particularly around homesteads and even hillsides are dominated by eucalyptus trees which are not expected to reduce soil erosion due to sparse nature of the canopies (FAO, 1988 cited in Bewket, 2003).

As it was observed during the field visit and stated by the focus group participants, removal of the top fertile soils and advancing gullies are common particularly in the margin of cultivated land in almost all parts of the watershed. According to local informants, during short and intense rains, rivers and streams occasionally change route and flow over agricultural and grazing lands, resulting in deposition of gravel, stone and boulder which make the land unsuitable for farming and grazing.

4.4.4. **Implications on Climate Change**

There is a complex association between land use/cover and climate change. Some of the key links include; the exchange of sensible heat between the land surface and the atmosphere. LULC influence local climate through absorption or emission of greenhouse gases and by modifying the physical properties of land surface (Foley et al., 2003; Bonan, 2015). Hence, changes in LULC (e.g. alteration of forest land to cultivated lands) can have intense impacts on yhe characteristics of surface climate interactions by modifying the exchange of heat energy, moisture, and surface albedo (Bonan, 2015; Richter and Houghton, 2011). As is well known, clearing forests for agriculture can have a considerable effect on evapo-transpiration rates which can increase probability of climate extremes such as drought incidences (Taylor et al., 2002; Verburg, *et al*., 2009).

While LULC change is an important driver of climate change, a changing climate can lead to changes in LULC (Dale, 1997; World Bank 2008a). For example, land users might shift from their habitual crops to a new crop types that will have better survival and production potential under changing climatic circumstances. Higher temperatures increase the probability of encroachment of cultivation towards mountainous areas (higher altitudes) which was onces covered by snowpack and afroalpine vegetation types (this was witnessed in this study). This implies that the interactions between climate change plays a significant role on LULC yransformation at different of spatial and temporal dimensions (Ellis and Pontius; 2006; EEA; 2010; IPCC, 2013b; Mahmood et al., 2010). As discussed so far, the study watershed is highly vulnerable to rainfall variability and climatic shocks like droughts.

4.5.5. **Implications on livestock Management**

The major animal feedin the Ethiopian highlands is natural pasture. Hence, any alteration in the availability and quality of grassland resources can lead to changes in the quantity and performance of the livestock sector. Such process has been apparently witnessed in the study watershed. As it was observed from satellite image analysis (Table 4.1), grassland areas retreated particularly for the last two study periods while the area of arable land increased over the years contributing to decrease in the supply of fodder for livestock. This is directly linked to the decrease in the livestock resources and livestock production. As it was noted from key informants and field observation farmers residing in the Wurch agro ecology of the watershed practices spontaneous transhumance, taking their cattle to graze on the top of afromontain region, particularly during the dry season and when livestock fodder is scarce.

Besides, the 2005 federal Rural Land Administration and Land Use proclamation of Ethiopia prohibited free grazing in land use where SWC works have been undertaken (Proclamation No. 456/2005, art. 13.3). Due to this restriction, livestock rearing is either forced to marginal lands or confined to small plots of available grazing lands, eventually leading to decline of livestock population (Zeleke, 2000). Livestock is an integral part for environmental sustainability and sound agricultural production systems in the Ethiopian highland. As Zezza et al., (2016) pointed out farm animals provide a wide spectrum of benefits to society such as revenue and employment, food and nutrition, manure, draft power and hauling services, savings and insurance, and environmental and health services.

Manure is among the most important contributions that livestock make to enrich soil fertility and sustainability. Hence, the decline in number of livestock has an impact on manure production and all other benefits obtained from livestock resources. It could also have an impact on soil fertility. This implies that the expansion of cultivated lands at the expense of grazing lands leads to lose of the contribution of livestock on SLM. In other words, the reduction in the number of livestock has negative implication on sustainable land management in the watershed (Zeleke, 2000).

4.5.6. Implications on the Use of Biomass for fuel energy

Due to a lack of cheaper alternative sources of energy, local communities depend on biomass energy (fuel wood, crop residues, and dung cakes) to meet their household energy needs (e.g. cooking, boiling, lighting, and heating) in all agro-ecological setting of the watershed. Thus, decline in woodlots and other tree species implies shortage of biomass source of energy for the rural household.

Summary

LULC dynamics in the form of degradation or restoration is natural and inevitable global phenomenon. This study has highlighted the magnitude, key driving forces and implications of LULC change in the Gedalas watershed during the forty-three years considered. From the analysis it was apparent that LULC conversion or transition was ongoing phenomena in the Gedalas watershed across various spatiotemporal scales. However, the consistent net gain in farmlands/settlements particularly at the expense of afro-montane ecosystems was the most prevalent in the watershed. There has been consistent increase in farmlands/settlement cover in the upland and, while shrub/bush land and grasslands area have continued to decrease. The analyses suggest that the afro alpine areas are prone to future transformations as well which implicates the continued degradation of its unique flora and fauna. Perceptions of the local communities on LULC change substantially agree with data from satellite images. The majority of the rural communities reported that there have been changes in the patterns of LULC in past decades.

The study clearly showed that LULC dynamics in the study area is an outcome of the combination of geophysical and socio-economic factors and complex processes including complex topography, rapid population growth and concomitant poverty, expansion of cultivated and settlement land, lack of alternative sources of energy, regime change and associated policy directives in the country were considered the primary driving forces in the study periods. Study also indicates that the LUCC in the watershed was evidently aggravated by environmental factors, such as recurrent drought and fragile physical attributes such as terrain features of the area.

LULC changes have significant implications on the biophysical and socio-economic characteristics of the watershed, which ranging from loss of terrestrial biodiversity, decline in vegetation cover, change in hydrological regimes, increase in soil erosion and sediment loads, change in local climate and other socio-economic impacts on local livelihoods and livestock management of the watershed. Hence, to mitigate these impacts, it is vital to recognize the link between the bio-geophysical and socio-economic processes leading to the land use/cover dynamics and associated land degradation. In this regard, the ongoing government initiated integrated watershed management and sustainable land management programs should be strengthened with genuine participation of local community.

CHAPTER FIVE

5 Soil Erosion Estimation and Severity Analysis Based on RUSLE Model and Local perception in the Beshillo Catchment of the Blue Nile Basin[10]

5.1 Introduction

As vividly highlighted in Pimentel (1993), soil is one of the most essential resources we have. But this basic resource is being adversely affected by various forms soil erosion (FAO, 2019). Water induced Soil erosion is the most prevailing form of land degradation in the highlands of Ethiopia, where huge amount of productive top soil is eroded annually. Soil erosion adversely affects crop productivity by reducing soil water availability, nutrients abundances, organic matter content, and, as the topsoil erods, by limiting rooting depth of the soil (Pimentel, 1993). Therefore, implementing SLM practices would be the most reasonable way to control soil erosion on the one hand and improve land productivity on the other. It is apparent that action to control soil erosion needs to be based on information and facts (Pimentel, 1993). *This chapter presents estimated magnitude of soil loss rates using Revised* Universal Soil Loss Equation (RUSLE) model coupled with local perceptions and field observations *in the Gedalas watershed of the Blue Nile Basin, Northeastern Ethiopia. Soil, land use/cover, DEM, rainfall and support practice data were used as an input parameter.*

5.2 Estimation of annual soil loss in Gedalas watershed

The computed annual values of soil loss of the watershed ranged from 0 in plain areas to well over 393 t /ha/yr. In the lower reach degraded sloping areas, banks of streams and at the specific spots of steep slopes of the watershed soil loss rate exceed 935 t /ha/yr (For a visual comparison of results, see Fig. 5.1). The annual mean soil loss value for the watershed was around 37 t/ha/yr, whereas soil loss rates on water courses averages 393 t/ha/yr, which comprises the largest quantity of annual mean soil loss rate per hectare in the watershed. This high soil loss rate could be attributed to the step slope and rugged nature of topography which makes soil erosion along river beds and banks high.

These are comparable to the loss of around 4 mm depth[11] of topsoil per year (*Hurni, 1983*). The overall average soil loss rates of the watershed are higher as compared to soil formation rate for the various land units of Ethiopia, which ranges from 2 to 22 t h^{-1} y^{-1} (Hurni, 1983). If we compared the estimated soil loss

[10] Part of this chapter is published as journal article as: Yesuph A.Y and Dagnew A.B. 2019. Soil erosion mapping and severity analysis based on RUSLE model and local perception in the Beshillo Catchment of the Blue Nile Basin, Ethiopia. *Environmental System Research, 8:17.*

[11] Hurni, (1983) stated that "1 tonnes annual soil loss per ha is equivalent to loss of 0.12mm soil depth in the area"

result to the limits of soil loss tolerance[12] suggested by Rose (1994) (10t/ha/yr for tropical region) and Hurni (1986) 2-18 t $ha^{-1}yr^{-1}$ for the various agro-ecological belts of Ethiopia and 10 t $ha^{-1}yr^{-1}$to the northern highlands of Ethiopia, it is still higher despite conservation efforts through an integrated watershed management approach in place. Moreover, as per the recommendation of Morgan (2009), annual soil loss threshold for the sustainable agricultural lands use is 10 tonnes ha^{-1}. According to Kouli et al. (2009), any soil loss rate which exceeds 10 t/ha/year will not be reversed in a time span of fifty to hundred years. Considering this threshold, the total area with a soil erosion risk higher than the soil loss tolerance (10 t/ha/year) was 13680 ha (Table 5.1 and Fig. 5.1), comprising 57.1% of the entire watershed area.

Table 5. 1: **Annual soil loss rates, magnitude and area coverage**

Soil loss Rates (t ha^{-1} y^{-1}) *	Severity classes*	Area (Ha)	% of total	Estimated annual loss (tones)	Av. Soil Loss rates (t ha^{-1} y^{-1})	Priority class for conservation
<5	Very slight	10290	42.9	46305.03	4.5	5th
5 to 15	Slight	7424	31	103193.6	13.9	4th
15 to 30	Moderate	2707	11.3	73089.56	27	3rd
30 to 50	Severe	1701	7.1	79947.35	47	2nd
>50	Very sever	1848	7.7	585816.55	317	1st
Total		23970	100	888352.10	100	

Source: * This classification was made based on soil erosion literature on the Blue Nile Basin (E.g. Haregeweyn et al, 2017)

However, it should be noted that the judgment of what level is tolerable depends on the local situation and in particular the type and depth of soil, the rate of soil formation, land use/cover status, topography and amount, intensity and duration of rainfall (Foster et al., 2002).

The estimated soil loss values and its spatial distribution in the watershed is generally reasonable, compared to what can be seen in the field and weighed against similar studies reported by FAO (1986) in the central and northern highlands (35 t/ha/yr) and SCRP (1996) in the South *Wollo* Zone (35 t/ha/yr).

Contrary to this finding, other similar studies undertaken in different parts of the highlands of the country reported a relatively higher average soil loss rate. For instance, the computed result of this study was lower than the mean soil loss rate of 243 t/ha/yr by Zeleke (2000) in northwestern highlands of Ethiopia; 93 t/ha/yr by Bewket and Teferi, (2009) in the Chemoga watershed; 84 t/ha/yr by Yihenew and Yihenew (2013) in Northwestern Ethiopia; 47.4 t/ha/yr by Gelagay and Minale (2016) in the Koga watershed; 45 t/ha/yr by Wolka et al.,(2015) in parts of Ethiopian rift valley, and from 0.2 to 321 t/ha/yr by Bantider

[12] As defined by Renard et al. (1997), "'the extent to which soil loss can be tolerated".

(2007) in the eastern escarpment of Wollo. Plot level experiments conducted in different SCRP stations at various spatial and temporal scales also showed differences in soil loss rates (e.g. at Andit tid 87-212 t/ha/yr (1983-1992); at Anjeni 131-170 t/ha/yr (1985 to 1993).

The above report highlights that though soil erosion endangers the soils in the Ethiopian highlands, the quantitative soil loss estimation is still uncertain and inconsistent. Nonetheless, it is imperative to note that all the above quantitative information pointed to general soil erosion problems in the highlands of Ethiopia in general and the study watershed in particular.

The possible causes of disparities in estimates could be differences in time and assessment scales, variations in input data, lack of correspondence in the methods adopted combined with the high heterogeneity of the environment in which the studies carried out. In this respect, Haregeweyn et al. (2015) reviewed that variation in mean annual rainfall and its associated erosive power was found to explain more than one-third (35%) of the soil loss variations.

5.3 Annual soil loss in Gedalas watershed

As demonstrated in Table 5.1, the annual average soil loss was grouped into five erosion intensity classes. The study revealed that 42.9 % of the watershed experiences very slight rates of soil erosion, whereas areas affected by slight and moderate rates of soil loss encompass 31% and 11.3% respectively. In total, areas affected by severe and very sever soil loss rates covers approximately 14.8% of the watershed (Table 5.1). This implies that most of the total soil loss was generated from the small areas which experiences high erosion rates.

From the from the spatial patterns of soil erosion hazard map (Fig 5.1), it is evident that nearly the whole watershed areas require implementation of one sort or more of SWC measures to ensure sustainability of land use. However, in the southwestern areas of the watershed, the extent of soil loss is relatively lower than the northeastern parts. This could be due to the fact that the southwestern part of the watershed was pilot sites of Sustainable Land Management (SLM) Projects and hence there are different conservation interventions such as area closure, terrace, grass strip management and controlled grazing, among others. Moreover, this part of the watershed is situated in mountainous regions of Afro/sub Afro alpine areas. Thus, it is relatively far away from direct and significant impact of accelerated soil erosion. Nevertheless, it ought to be noted that since this part of the watershed is characterized by highly elevated, steep slope and rugged topographic areas, the actual soil loss rates may be underestimated as RUSLE model cannot predict soil loss from caused by gravity flow.

Most of the current soil erosion risk areas are spatially confined in the steep slope Northeastern parts of the watershed. It is believed that this part of the watershed is primarily characterized by shallow soils, Steep slopes, and sparse vegetation covers. Moreover, unsustainable land management practices on sloping lands have accelerated the magnitude of soil erosion. During the field visit, this part of the watershed comparatively exhibited low level of SWC structures and removal of the vegetation cover.

Therefore, it should be realized that these parts of the watershed need urgent and prioritized intervention with appropriate SWC measures by the local governments. In fact, as observed from the field survey and information obtained from local informants, there were long aged attempts to delineate and put aside steep slope areas in this part of the watershed as enclosures. However, sustaining the positive achievements in controlling soil erosion is still a major challenge in the area.

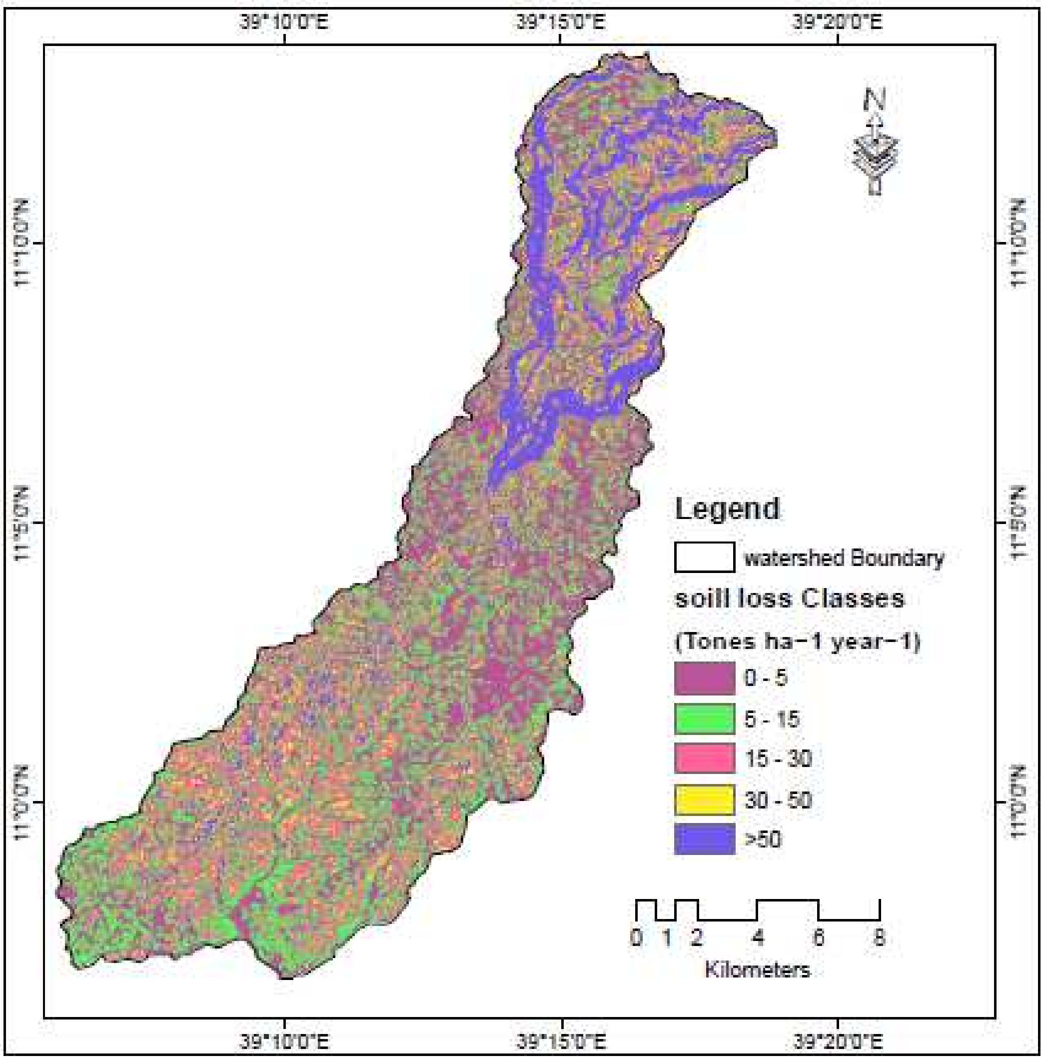


Figure 5. 1: Spatial variation of soil erosion loss in Gedalas watershed

5.3.1. Soil Erosion along Slope Classes of the watershed

As noted above, slope angle and slope length are the two main factors which significantly influence soil erosion rates in the study area. As expected, areas with steep slope topography have much more soil erosion rates than areas with gentle slopes. The results clearly demonstrate that almost 2/3rd of the watershed area (70.6%) situated on the sloping terrain. When viewed from slopes perspective, the spatial distribution of soil loss rates increases linearly with increasing slope gradient across the watershed (Table 5.2). The watershed areas with slope gradients higher than 60% experiences soil loss rates ranging from 91-935-ton ha^{-1} yr^{-1}. This implies that slope plays significant role in accelerating soil erosion rates in the area and hence a reduction in slope length through various SWC structures should be a concern of priority. In agreement with the model estimated outputs, local community perceptions and evaluation also indicate the occurrence soil erosion primarily on steep slopes areas all over the watershed suggesting the need for comprehensive SWC measures in accordance to slope classes.

Table 5. 2: Soil loss values for various slope classes of the Watershed

Slope Classes (%)	Total Area		Estimated annual loss	
	Ha	%	tones yr^{-1}	Contribution to total soil loss (%)
0 -5	1094	4.6	3883.2	0.4
5-10	1426	5.9	20321.2	2.3
10-15	2790	11.6	44702.8	5
15 - 30	3161	13.2	224572.2	25.3
30 - 60	6667	27.8	294051.0	33.1
>60	8832	36.8	300821.6	33.9
Total	23970	100	888352.1	100

5.3.2. Soil Erosion across Agro Ecology in Gedalas Watershed

As depicted in Table 5.3, the estimated annual loss values varied across agro-ecologies of the watershed, regardless of land use/cover types and slope classes, with greater loss per unit area occurring from *Weyna Dega* compared with *Wurch* and *Dega* Areas. Although the observed contribution to total proportion of land area is higher in *Wurch* zone (48.7%) and *Dega* zone (44.6%) as compared with *Weyna Dega (6.7%),* the highest soil loss per unit area (Total soil loss to plot area ratio) is occurring in the steep slopes part of the watershed suggesting the need for targeted SWC measures and treatment of degraded landscapes. The possible explanation for the incidence of high rate of soil loss in the *Weyna Dega* area is the prevalence of steeper slopes along with farming on marginal lands which is not conducive for agriculture.

It is apparent that the *Wurch* zone of the watershed shows the relatively low erosion rate relative to its total areas. This could be most likely attributed to presence of SLM pilot project working on the rehabilitation of degraded lands. A relatively lower soil loss in this zone also implies that project supported SWC activity play a vital role in controlling soil erosion in the watershed.

Table 5. 3: Variations of Soil Erosion by Agro Ecology

Agro Ecology	Area		Estimated annual soil loss (t y^{-1})	Av. Soil Loss rates (t ha^{-1} y^{-1})	Contribution (%)
	(ha)	%			
W/Dega (1919-2300 m)	1614	6.7	139268.3	86.3	15.7
Dega (2300-3200 m)	10682	44.6	505720.5	47.3	56.9
Wurch (3200-4233 m)	11674	48.7	243363.3	20.8	27.4
Total	23970	100	888352.1	37.1	100

5.3.3. Soil erosion across LULC categories

This study reveals considerable effects of LULC class on the extent of soil erosion in the watershed. According to RUSLE model, results estimated total annual soil losses by water erosion were highest for croplands followed by grazing lands of the watershed. Higher soil loss in cropland is likely caused by cultivation on steep slopes, intensive plowing and mono cropping practices while high soil losses in grazing lands are associated with intensive grazing which results in removal of vegetation cover and soil compaction caused by trampling of livestock. This result, however, contradicts with the plot level finding of Nyssen et al. (2009a) who documented higher soil erosion values for grazing lands as compared to that of croplands in Tigray.

The differences may be due to variations in the prevailing environmental conditions (slopes, vegetation composition, climate, soil characteristics, and land management practices) and adoption of different modeling approaches by the researchers while calculating C-factor values in their specific study areas. It is evident from the result that the pattern of onsite soil erosion is associated with poor land management activities and suggests the need for promoting SLM practices in the watershed.

Table 5. 4: Soil erosion by land use/cover types

Land use/Cover Type (2017)	Area (ha)	% of total	Estimated annual soil loss (tones)	Av. Soil Loss rates (t ha^{-1} y^{-1})	Contribution (%)
Afro/Sub Afro alpine vegetation	3513	14.66	61152.28	17.4	6.9
Bare lands	613	2.56	14374.23	23.4	1.6
Farmlands/ Settlements	12815	53.46	378202.6	29.5	42.6
Grazing lands	3040	12.68	310685.4	102.2	35
Shrub/bush lands	3010	12.56	42172.6	14.0	4.7
Water courses/ beds	91	0.38	35799.14	393.4	4
Woodlands/plantations	888	3.7	45965.82	51.8	5.2
Total	23970	100	888352.1	37.1	100

5.4 Farmers' perception[13] of Soil erosion damage in the watershed

There is an overall consensus that the model-based estimation of soil erosion output could be ascertained by integrating local knowledge and perceptions of soil erosion problems. It has been also realized that understanding local perceptions and knowledge of soil erosion are vital entry points to make informed decisions on SLM practices (Amsalu, 2006; Weldemariam et al., 2013). In this line, Herberlein (1972) stated that at the point when local communities comprehend that their physical environment is deteriorating and felt personally responsible for these outcomes, they will endeavor to control land degradation inducing actions and will show more interest to support land management programs.

With this in mind, farmer's perceptions of soil erosion incidence, levels, indicators and impacts were assessed across the three agro ecologies of the watershed. As shown in Table 5.5, over 98% of the farmers participating in the survey were aware of soil erosion problems - 95% in Wurch, 100% in *Dega,* and 100% in *Weyna Dega*. Further discussions with the local community revealed that the incidence of soil erosion damage was critical during the onset of rainy season and at times of seedbed preparation where the soil is bare and loose. Moreover, during field observation, rill erosions and rock exposures were intensively visible on the arable plots and its environs suggesting the severity of soil erosion in the watershed though different attempts were/are in place to address problem. The result is comparable with the findings of other similar studies conducted elsewhere in the highlands of Ethiopia (e.g. Amsalu, 2006).

Concerning the level of the soil erosion problem, over half of those respondents (59% of total) who perceived soil erosion as a problem rated it as severe, 26% rated it as moderate while the remaining 10% and 5% rated it as minor and difficult to estimate respectively. Though farmers were not capable of quantitatively estimate level of soil loss per unit area, it is clear from the data that all of them acknowledged the existence and level of soil erosion in their localities. However, there is a minor difference as observed across agro ecologies. The majority of farmers residing in *Weyna Dega* and *Dega* areas recognized the problems as more severe compared to *Wurch* areas. As reflected from local residents, the status of soil erosion in the *Wurch* agro-ecology (upstream areas) seems relatively low. As already noted, this is most likely attributed to the SLM interventions since the late 2014 in the area (TWARDO, 2017). This result is comparable to computed erosion rates of the RUSLE model and to what can be seen in the plots. However, the results contradict with those of Bewket and Sterk (2003) and Tefera and Sterk (2010), who

[13] Perception is a set of internal sensational cognitive processes of the brain at the subconscious cognitive function layer that detects, relates, interprets, and searches internal cognitive information in the mind (Wang, 2007).

reported that "*the perceived severity of soil erosion was location specific, that is, relatively higher in upstream areas and lower in downstream fields*".

Farmers were asked to point out the trend of soil erosion over time in their localities. Results showed that the majority (68%) of farmers perceived an increasing trend of soil erosion while 9% and 23% of the respondents felt a decrease and no change over time respectively (Table 9). Those who reported that the problem was increasing were mainly from the *Weyna Dega* agro ecology where most of the area of the watershed lies on steep slopes. Responses in no change of soil erosion (40%) were prominent in the middle portion of the watershed. This may be ascribed to the high proportion of moderately sloping land.

Farmers were asked to list soil erosion indicators which they observed in their localities and their croplands. The most frequently mentioned key indicators in almost all agro ecologies were reduced crop yield and performance (93%), the removal of seeds and seedlings (91%), decrease in soil depth (86%), increase in on farm stoniness and gradual rock exposure to the extent that prevent plowing (79%), frequent damage of conservation structures (72%), changes of soil color (70%), development of visible rills on the bare soils (68%), field dissection and formation of gullies (64%), exposure of trees/crops roots (64%) and deposition of sediment on the lower section of the farm (63%) (Table 5.5). These soil erosion indicators perceived by the local communities are matched with most of the indicators identified in the scientific literatures (e.g. Lal, 2001, Morgan, 2009), suggesting accuracy of community- based information as an alternative view of the problems. However, there was slight variation from one site to another in the number of farmers appraising these indicators. For example, in some areas, notably in the *Dega* agro-ecology, development of visible rills on farmlands after erosive rain was acknowledged as major indicators by the majority of the respondents. In contrast, a few farmers pointed out that field dissection, the formation of gullies, sediments deposition and change in depth of surface soil as significant indicators of soil erosion.

Moreover, though confined to limited areas, some key elderly informants reported the emergence of some unusual plant species (e.g. quickly spreading weed species) that signify the indicator of existence soil erosion problem in their specific sites. These impact indicators were further confirmed by the majority of focus group participants and even by local development agents.

An attempt was made to appraise the spatial distribution of the recognized indicators over the farm lands along different agro-ecologies. Results revealed that almost all the above listed indicators were observed in the entire watershed despite ongoing watershed development program. The remarkable presences of all these soil erosion indicators imply that soil erosion is still the most serious form of land degradation in the watershed.

Figure 5. 2: Indicators of Soil erosion problems in the watershed (Photo: author, 2016

Table 5. 5: Farmers' views of soil erosion problems (% of respondents)

Farmers' perceived responses to:	W/Dega (N= 76)	Dega (N=194)	Wurch (N=114)	Overall (N= 384)
Erosion faced in the locality (%)				
Yes	100	100	95	98
No	0	0	5	2
Soil erosion level (%)				
Severe	68	59	51	59
Moderate	20	27	31	26
Minor	9	8	13	10
Difficult to estimate	3	6	5	5
Change of soil erosion over time (%)				
Increasing	91	57	56	68
Decreasing	0	3	24	9
No change	9	40	20	23
Indicators of soil erosion Problems (%) @				
Field dissection and formation of gullies	77	42	73	64
Development of visible rills on farmlands after erosive rain	54	89	62	68
Deposition of sediment on the lower section of the farm after rainfall	71	56	62	63
Decrease in soil depth	96	75	87	86
The removal of seeds and seedlings	96	91	89	91
Trees/crops root exposure	76	68	65	64
Increase in stones cover and rock exposure	95	64	89	68
Poor crop yield and vigor	94	89	96	93
Damage of conservation structures	84	62	71	72
Changes in Surface soil color	43	27	57	70

@Percentage does not add up to 100 as farmers have listed more than one indicator
Sources: The author, 2017

To gain further insight into the farmers' awareness of erosion, they were interrogated to state the major causes that initiated soil erosion in their respective localities. Although some farmers held the belief that supernatural resentment is the cause for the occurrences of soil erosion in their explanations, the majority of the respondents put emphasis on combinations of causes. For instance, topography of the area, intense rainfall, poor vegetation cover and destruction of conservation structures were the most commonly ascribed causes for the ongoing soil erosion problems in the watershed (Table, 5.6 In this vein, a 79 years old key informant farmer from the *Weyna Dega* area of the watershed lamented his concerns about the problem of deforestation brought about by some farmers on the future fate of farming as follows:

> *Some individuals don't care about their land on which their livelihood depends. They know that vegetation reduces soil erosion and improve soil fertility, but still they destroy vegetation covers as they are only interested to expand their farm land and get more produce''. Another key informant from Wurch zone attributed soil erosion problems, mainly to "heavy rainfall and to frequent damage of conservation structures due to incorrect installation.*

Though their percentages are relatively small, farmers also pointed out cultivation on steep slopes, the nature of the soil itself, over grazing and its associated impact as additional causes that facilitate soil erosion in their respective localities. In addition, a few (21%) farmers mainly from *Dega and Wurch* agro ecologies also mentioned that their croplands had become more vulnerable to erosion because of runoff from damaged conservation structures, roadside and culverts. In FGD, in all locations, farmers concurred that they had experienced these causes, although, most farmers emphasized steep slope as the principal causes of soil erosion.

Table 5. 6: Farmers' perceived causes for soil erosion (% of respondents)

Causes of soil erosion (%)	W/Dega (N= 76)	Dega (N= 194)	Wurch (N= 114)	Overall (N= 384)
1. Erosive rains	79	89	77	82
2. Soils being erodible	17	13	19	16
3. Topography of the area	99	75	94	89
4. Decline in vegetation cover	100	100	100	100
5. Damaged conservation structures	89	77	73	80
6. Cultivation on steep slopes	30	23	34	29
7. Runoff from roadside drainage and culverts	5	35	23	21
8. Over grazing and impacts of cattle tracks	33	21	23	26

@Percentage does not add up to 100 because of multiple responses

Sources: The author, 2017

Furthermore, farmers were asked to list the possible effects of soil erosion and they mentioned; loss of fertile soil, declining soil fertility, loss of seeds, loss of chemical fertilizers, ever increasing fertilizer requirements. Surprisingly, farmers' perception concurs with existing scientific literature (Lal, 2001).

However, the majority of farmers' frequently associated soil erosion impact to decline in crop production. Most key informants and discussants bear similar sentiments about the impacts of soil erosion in the watershed. For instance, one key informant (farmer) residing in the *Weyna-Dega* area highlighted his perceived soil erosion impact indicators this way:

> *Formerly, my farmland was among good land, as it was growing everything. Recently, crop production has been declining over time due to soil erosion. Whatever seed I sow productivity is too low, sometimes the crop leaves turn yellow and they finally die. The soil fertility status is poor now; it is becoming shallow and stony. We are living by scratching such lands like a hen.*

Finally, farmers were asked to recommend possible solutions and curative actions to the prevailing soil erosion problems in their localities. The majority of respondents suggested more than one possible solution including construction and maintenance of terraces, planting of fast-growing economic trees, enclosed degraded hillsides until it rehabilitates, and implementation of proper cropping systems and other related land management practices. They further recommended Strict follow up of government regulations and respecting local bylaws set out by the farmers themselves to deal with illegal interferences by humans and livestock to enclosed areas and farmers' encroachment onto marginal land that is very susceptible to erosion.

The overall results of this empirical analysis provide clear evidence that though the depth of understanding varies due to differences in socioeconomic characteristics among individuals, the majority of farmers have unequivocal and relatively inclusive sets of knowledge about prevailing soil erosion problems, indicators, causes, consequences and even remedial actions and solutions to the problem in their localities across the agro-ecologies, implying that engaging farmers can provide accurate information in assessing land degradation-restoration dynamics at local scales. This awareness of soil erosion problems probably stems from the information they acquire through their networks, their own experiences and their exposure to the government awareness campaigns. The result concurs with the findings of previous and contemporary similar research conducted elsewhere in Ethiopia (Bewket and Sterk, 2003; Karltun et al., 2013; Gebremichael et al., 2015; Meshesha et al., 2012; Assefa and Hans-Rudolf, 2016; Nigussie et al., 2017).

Summary

Water induced Soil erosion is the most prevailing form of land degradation in the highlands of Ethiopia in general and the study area in particular, where huge amount of fertile soil is being lost annually. The objective of this study was to estimate soil erosion hazard in the Gedalas watershed of the Blue Nile Basin, Northeastern Ethiopia. The estimation was carried out by using Revised Universal Soil Loss Equation (RUSLE) model coupled with local perceptions. Soil, land use/cover, DEM, rainfall and support practice data were used as an input sets to find RUSLE parameter values. The raster layers were processed to present the required input parameters in ArcGIS platform and finally the inputs were multiplied together to quantify annual average soil loss rate and generate intensity maps in the watershed.

The estimated annual mean soil loss of the entire watershed was found to be 37-ton ha^{-1} $year^{-1}$, which is higher than the maximum tolerable value of soil loss (16 t ha^{-1} yr^{-1}) and the annual erosion rates range from 0 to above 935 tonnes $ha^{-1}year^{-1}$. The annual mean soil loss values below 5 tonnes ha^{-1} $year^{-1}$ were rated as very slight, while those above 50 tonnes $ha^{-1}year^{-1}$were categorized as very severe soil erosion risk. Areas experiencing values between these two were further classified into slight, moderate, and severe erosion zones. Soil loss in more than 1/3rd of the study area (36.4 %) was below moderate (<= 15 tonnes $ha^{-1}year^{-1}$). Nearly one-fourth (25.5%) of the watershed area experienced moderate (between 15 and 30 tonnes $ha^{-1}year^{-}1$) soil loss values. Only 14% of the watershed areas classified under severe to extremely severe (above 30 tonnes $ha^{-1}year^{-1}$) soil erosion risk zones. While 62 % of the watershed still undergoes from very slight to moderate levels of soil loss, yet 72.6% of soil erosion occurred in zones less than 3200 m in elevation which accounts for 51% of the total area of the watershed. The study also demonstrated that the northeastern parts of the watershed suffer more from high soil erosion risk due to steep slope and rugged landforms of the area. Similarly, 43 % and 35 % of soil erosion occurred on cropland and grasslands areas, respectively. The quantitative soil loss estimation results and farmers' perception of soil erosion revealed that soil erosion has still remained significant problems in the watershed. The results underscore the urgent need for comprehensive and site-specific SLM practices in the watershed.

CHAPTER SIX

6 Soil properties across agro-ecologies and land use/cover types in Gedalas Watershed: Implications for SLM practices

6. 1 Introduction

Low actual land productivity caused by improper land use practices and topographic effects that leads to accelerated soil erosion and subsequent depletion of soil physicochemical Properties is the main challenges in the highlands of Ethiopian (Haileslassie et al., 2009).Maintaining soil fertility status is, therefore, a most important concern to sustaining crop productivity and environmental sustainability. Assessement of soil properties in relation to LULC types and agro-ecologies are vital to design appropriate sustainable land management interventions plans and actual-practices.

This section presents the existing status of soil physico-chemical properties under selected land uses/cover types (shrub, grasslands and cultivated land) and agro-ecological zones (*Wurch, Weyna- Dega* and *Dega*) of the watershed based on soil test results. Measured soil physico-chemical characteristics were compared with desired range values (threshold level) that must be available for normal functioning of the soil using FAO and other guidelines. Table6.1 shows the mean values and ANOVA results of topsoil (0-20cm) physico-chemical properties under selected LULC classes and of agro ecological zones. Table 6.1 shows mean soil physico-chemical properties under different LULC types based on agro-ecologies.

6.2 Soil physical properties in relation to land use types & agro-ecologies

6.2.1. Particle size Distribution

Particle-size is a basic property of any soil as it provides important clues to nature and derivation of soils. Particle-size distributions influence a variety of other soil properties such as the amount of nutrient reserves, size & spacing of soil pores, pore space distribution, extent of aeration (circulation of air in the soil), soil water content, water flow (drainablity), erodiblity, workability (ease of tillage), soil temperature, nutrient mobility and uptake, rate & extent of chemical reaction, nutrient retention, amount & frequency of irrigation, water intake rate, and specific surface area(Brady and Weil, 2002; FAO, 2006b).Soil texture also influences organic matter content, root elongation, soil respiration, root litter decomposition, vulnerability to erosion, cation exchange capacity (CEC), and pH buffering capacity among others (Yolcubal et al., 2004).

The laboratory textural results and class determinations analysis revealed that variations were more observed among agro-ecologies than LULC types of the entire watershed. The average percentage sharing of the sand fraction varied among agro-ecologies (Table 6.1). Accordingly, the lowest mean sand content (25.33%) was recorded on *Dega* agro-ecology, while the highest mean sand content (38.83%) and (38.24 %)

were registered on soils of *Weyna-Dega* and *Dega* zones respectively. This difference was found to be statistically significant at P< 0.05 (F=15.551, p = 0.004) (Table 6.1), suggesting sand content of soils was higher at *Wurch* and *Weyna Dega* Zones as compared to *Dega* Zone. Similarly, the lowest mean clay fraction (32.03%) was recorded in soils of *Wurch* zone, while the maximum clay content (48.98 %) was recorded in soils of *Dega* agro-ecology. The mean value of clay fraction for *Weyna-Dega* zone was relatively similar to that of *Wurch* zone (35.97%). Hence, the differences in clay content of soils between *Dega* agro-ecology and the other two are statistically significant at P< 0.05 (F=19.857, p = 0.002) (Table 6.1). On the other hand, though there were slight variations in mean silt content of soils across agro-ecologies, this disparity was not statically significant (p > 0·05). The overall mean silt content value of the soil in the entire watershed is low (26.5%). This could be ascribed to the prevalence of water induced soil erosion problems as silt fractions are typically the most erodible and easily transported particle by running water (Koiter et al., 2017).

The variation in sand and clay content across agro-ecologies could be topographic variations and selective removal of clay particles by soil erosion processes. For example, as it was indicated in soil erosion risk map of the preceding section (Chapter-V), the *Wurch* and *Weyna Dega* zones have been dominated by steep slope landscapes and prevalence of high erosion rates which may erode clay components. The relatively high clay and silt content of the soil on the *Dega* zone could be partly attributed to the flat and low slopping nature of the topography and associated low geomorphic soil erosion risks, and comminution of larger particles, generally primary minerals that are inherited from the clay delivering parent materials (Alexander, 2014).Based on FAO (2006) guidelines, clay (*Dega* Zone) and clay loam (Wurch and Weyna Dega zones) were the dominant soil textural designations in all land use types across agro-ecologies in the watershed.

Pertaining to watershed level effects of LULC types on soil particle distributions, the highest mean values of sand (36.20%) and silt (28.30%) fractions were detected in the shrub lands while the lowest sand (33.06%) and Silt (25.78) components were recorded in grasslands and cultivated lands respectively. With regard to clay contents, the highest mean value (44.0%) was registered in cultivated lands, followed by grasslands (40.2%), while the lowest was observed from Shrub lands. The highest mean silt value for shrub lands, followed by grasslands (26.51%) could be attributed to the prevalence of a relatively better vegetation/grass cover which reduced loss of silt fractions by processes of water erosion, implying conversion of these land use types into croplands could provoke risks of soil erosion.

A one-way analysis of variance (ANOVA) test was conducted to explore the differences on mean values of soil textural components (sand, silt, clay contents) among the three dominant land use/cover types at watershed. However, though there was slight variation in all these components among land use types across agro-ecologies, there was no statistically significance difference (at $P<0.05$ level) registered among the three LULC types in the surface layers ($\leq$ 20 cm depth) in the watershed.

6.2.2. Bulk and particle densities

Bulk density is an important parameter for the description of soil quality as its value suggests soil status for porosity, Plant root penetration, aeration, and hydrologic function, such as water infiltration and retention (FAO, 2006a). The mean bulk density value of the soils in the study watershed slightly varies both among LULC types and agro-ecologies. However, one-way ANOVA analysis result revealed that this variation was not statistically significant (at $p< 0.05$). For land use/cover types, the highest and lowest mean bulk densities values were recorded for soils from shrub lands (1.63 g cm^{-3}) and grasslands (1.56 g cm^{-3}) of the Watershed respectively. The variation of soil bulk density among the LULC type might be attributed to the variation of soil texture, associated porosity, management and organic matter content (Celik, 2005). Contrary to Teferi et al (2016), who investigated higher bulk density under the grasslands, in this study the lowest mean bulk density was recorded under the grassland soils. This could most likely be attributed to the relatively high organic matter contents (Table 6.1). The mean bulk density of cropland was 1.56 g cm^{-3} which is higher than the critical value (1.4 g cm^{-3}) for agricultural use (Hillel, 1980), implying that such soil porosity is not idyllic for water movement and retention, root growth and air circulation which in turn has implications for agricultural productivity (Brady and Weil, 2002, FAO, 2006). The mean bulk density value of soils of cultivated land for this study was higher than the reports of Asmamaw and Mohammed (2013) in similar land use/cover type (1.17 g cm^{-3}) at Gerado catchment of northeastern Ethiopia.

Likewise, the highest (2.65g cm^{-3}) mean values of particle density were recorded at the grasslands while the lowest (2.62 g cm^{-3}) mean values of particle density were registered in shrub lands.This variation could be attributed to variations in organic matter content and mineral content (*for example,* particle density of Quartz (2.65 g/cm^3); Kaolinite (2.40 g/cm^3); Apatite (3.25 g/cm^3) (Osman, 2012*:56*). Nevertheless, the overall particle densities of the watershed soils were within the range of the density of most mineral soils which varies from 2.60 to 2.75 g cm^{-3} (Hillel, 2004; Brady and Weil, 2002).

Soil bulk and particle densities also showed slight variations among agro-ecologies in the watershed. For example, the highest bulk (1.61g cm^{-3}) and particle (2.66 g cm^{-}3) densities were recorded at *Wurch* agro-ecology while the lowest bulk density (1.49 g cm^{-}3) and particle density (2.62 g cm^{-}3) were observed at *Dega* and *Weyna* Dega agro-ecologies respectively. However, there was no significant difference ($p > 0{\cdot}05$) between the agro-ecologies in both in bulk and particle densities at the depth of 0–20 cm in the watershed.

6.2.3. Total porosity

As noted by Brady and Weil (2002), soil porosity is an essential soil characteristic that determines the dynamics of such soil properties such as gas diffusion, water flow and retention, heat flow and temperature regulation, nutrients flow and also the available space for plant root. An attempt was made to quantify the total porosity of soil based on the mean value soil bulk density and particle density among land use/cover types and agro-ecologies. Despite there was some sort of spatial variations, the mean values of the analysis did not exhibit statistically significant variations among the three LULC types and the three agro-ecological belts at $P < 0.05$ (Table 6.2). For instance, for land use/cover types, the lowest mean of soil porosity (37.87%) was recorded in shrub lands, while the highest mean of soil porosity (45.19%) was recorded in grasslands. The lowest total porosity recorded in a shrub lands as compared with that in the cultivated lands and grassland soils could be attributed to low clay content and low organic matter content of the soils. On the other hand, the highest total porosity associated to grassland use types might be due to the high clay content and organic matter content (Table 6.1), implying the positive effect of clay composition and organic matter content on total porosity of soils.

Agro-ecologically, the lowest mean of soil porosity (39.41%) %) was recorded in the *Wurch* zone, while the highest mean of soil porosity (43.09%) was recorded in *Dega* zone. These variations might be associated to differences in topography and associated soil particle distributions. As it was noted above, *Dega* zones constitute the highest clay content of the soil which implies more total porosity. As per FAO (2006a) rating of total porosity, the mean total porosity values of most soils in the watershed lies above 35 % and rated as medium and above, suggesting minimum risk of compaction problems and restriction of root growth due to excessive strength. However, porosities between 50% and 65% are generally quite favorable for optimum plants growth (Alexander, 2014).

Table 6. 1: Mean soil characteristics and ANOVA results of selected soil physico-chemical properties for different land use types and Agro-ecologies in Gedalas Watershed

Selected soil characteristics	Dominant Land Use type						Agro-Ecology					
	ultivated lan	Grasslands	Shrub lands	Average	F	P	Wurch	Dega	W/Dega	average	F	P
Sand (%)	33.16	33.06	36.2	34.14	0.146	0.867ns	38.24	25.35	38.83	34.14	15.551	0.004**
Clay (%)	44.05	40.42	35.5	38.99	0.334	0.728 ns	32.03	48.98	35.97	38.99	19.857	0.002**
Silt (%)	25.78	26.51	28.3	26.87	0.51	0.625 ns	30	25.67	25.2	26.51	2.022	0.213 ns
BD (g cm^{-3})	1.56	1.45	1.63	1.55	3.167	0.115 ns	1.61	1.49	1.54	1.55	0.831	0.483 ns
PD (g cm^{-3})	2.64	2.65	2.62	2.64	0.514	0.622 ns	2.66	2.63	2.62	2.64	1.685	0.263 ns
Total Porosity (%)	40.85	45.19	37.87	41.31	3.862	0.084 ns	39.41	43.09	41.42	41.31	0.493	0.634 ns
pH H_2O (1:2.5)	6.1	6.41	6.68	6.4	1.041	0.409 ns	5.87	6.8	6.7	6.46	6.311	0.033*
EC (dsm^{-1})	0.09	0.11	0.1	0.1	0.271	0.772 ns	0.09	0.1	0.11	0.1	0.271	0.772 ns
OC (%)	1.36	1.66	1.45	1.49	18.818	0.003**	1.53	1.5	1.44	1.49	0.078	0.926 ns
TN (%)	0.19	0.36	0.26	0.25	42.805	000***	0.23	0.24	0.27	0.25	0.061	0.942 ns
Av.p (ppm)	11.87	7.4	8.75	9.34	2.478	0.164 ns	6.62	10.99	10.41	9.34	2.853	0.135 ns
CEC($Cmol_c kg^{-1}$)	43.82	47.27	47.3	46.13	16.473	0.004**	46.28	46.69	45.42	46.13	0.256	0.782 ns
exchK($Cmol_c kg^{-1}$)	0.33	0.78	0.66	0.59	2.784	0.14 ns	0.49	0.56	0.72	0.59	0.445	0.66 ns
exch.Na($Cmol_c kg^{-1}$)	0.31	0.21	0.24	0.25	2.013	0.214 ns	1.27	0.23	0.26	0.25	0.23	0.801 ns
exch.Ca($meq100g^{-1}$)	32.12	28.15	33.91	31.39	5.717	0.041*	31.07	31.72	31.38	31.39	0.024	0.976 ns
exch. M ($Cmol_c kg^{-1}$)	9.77	12.24	8.71	10.24	26.226	0.001**	10.38	10.49	9.85	10.24	0.098	0.908 ns

** Significant at 0.01 *Significant at 0.05 NS – Non significant
Sources: Field Survey and laboratory analysis (2017)

Note: Soil samples were collected from more or less similar slope class for both similar land use types and different agro-ecologies

6.3. Chemical Properties of the soils across the land uses types and agro-ecologies

6.3.1. Soil pH and electrical conductivity

Soil pH influences the nutrient transformations, solubility, and availability as well as many other processes in the soil environment (Brady and Weil, 2002; FAO, 2006b). In this study, the effects of selected LULC types and agro-ecologies were assessed on the mean pH (H_2O) values and electrical conductivities of soils using one-way ANOVA. The result revealed that the lowest mean pH value (6.10) was recorded under cultivated lands, whereas the highest mean pH value (6.68) was registered in the soils of shrub lands (Table 6.1).This slight variation of soil pH across the LULC types might be ascribed to the differences in land management strategies such as tillage practices and cover management in the watershed. However, this mean pH values variation between the three-land use/cover types at the depth of 0–20 cm was no significant (at $p > 0{\cdot}05$), suggesting that soil pH do not show variations among LULC types in the watershed. This is concomitant with finding of Bewket and Stroosnijder (2003) and Teferi et al (2016) who examine the non-significant effect of LULC types on soil pH values in Chemoga and Jedeb Watersheds of the Blue Nile basin, respectively. However, it disagrees with other findings that indicated significant variations in soil pH values among LULC types in Sudan (e.g. Biro et al., 2013).

With reference to agro-ecology, the mean pH values of soils range from 5.87 in the *Wurch* zone to 6.8 in the *Dega* zone of the watershed. *Wurch* zones exhibits the lowest mean pH value (5.87) as compared to *Dega* (6.80) and *Weyna Dega* (6.70) zones in the watershed. The difference was statistically significant at p < 0.0.5 ($F=6.311$, $p = 0.033$), implying variations in pH characteristics of soils are explained by agro-ecologies (Table 6.1). The findings of this study are in line with Teferi et al (2016) who reported variations of pH value in altitudes.

The lowest value for *Wurch* agro-ecology could be mainly due to a relatively high amount of precipitation and associated high rate of leaching of basic cations from the top soil through runoff comparatively due to its location on highest elevation and steep slope terrain in the watershed. However, the mean pH values of the entire watershed fall within the ranges from slightly acidic to neutral (Foth and Ellis, 1997). Similar reports were forward by Griffiths et al (2009) who investigated significant difference in pH values between higher and lower altitudes in the Oregon Cascade Mountains of USA, where the highest was recorded for the later.

The finding also indicates that the mean electrical conductivity (EC) values of the soils of the watershed ranged from 0.09 $dscm^{-1}$ for cultivated lands of *Wurch* zone to 0.11$dscm^{-1}$ under grasslands of *Weyna-Dega* zone (Table 6.1). The relatively high value of EC in grasslands of Weyna Dega zone could be attributed to the leaching of basic cations from soils and associated decline in soil carbonate contents (Biro et al., 2011). The general EC values analysis indicates the salinity effect on plant growth is negligible in the watershed.

6.3.2. Soil organic Carbon/organic matter

Theoretically, variations in climates and landforms results in different kinds of plant communities and this in turn results in different amounts of organic matter with different compositions in the soil environment (Alexander, 2014). The amount of organic carbon depends on the texture and the clay content of the soil (FAO, 2006). Soil organic carbon (a proxy for soil organic matter) is a crude indicator of the general status of soil's nutrient cycling potential and stability of structure which in turn have direct implications on water infiltration capacity, soil biodiversity, vulnerability to erosion, and ultimately the productivity. Soil organic matter (SOM) content can also be used as a proxy indicator of the soil's potential to supply nitrogen to plants as the nitrogen content in SOM is comparatively constant (FAO, 2008). This study revealed a positive and significant correlation between organic carbon and total nitrogen values ($r= 0.89$, $P < 0.01$). The mean organic carbon (OC) content of the soils in the watershed ranged from 1.36 % to 1.66 % among land uses types. Significantly higher mean organic carbon value was recorded under grasslands as compared to cultivated and shrub lands ($F=18.818$, $p = 0.003$) (Table 6.1). The differences might be attributed to the level of organic matter inputs, variation in rates of litter decomposition, and cultural practices. For instance, the lowest OC content was noticed under cultivated land use/cover types of all agro-ecologies as compared to grass and shrub lands use/cover types within the same agro-ecology. The observed differences could be attributed to the differences in the types of plant/crops grown, level of organic matter inputs, the removals residue with crop harvest, intensity of cultivation, and repeated plowing practices which disperses aggregates and enhanced the process of organic carbon oxidation (Bewket and Stroosnijder, 2003; John et al., 2005). This signifies that conversion of grasslands and shrub lands to cultivated lands could result in a notable decline in soil organic carbon content.

In terms of agro-ecologies, the value ranges from 1.44 % (in *Weyna Dega*) to 1.53 % (in *Wurch*) zones. In conformity with a study by Teferi et al (2016), the highest mean value for *Wurch* zone could be attributed to the low temperature of the area which reduced the rates of soil organic matter decomposition. However, this difference was not statistically significant (at $P <0.05$). Though there was slight variation across land uses types and agro-ecologies, the overall organic carbon content of the watershed was categorized under very low (<2) and below the critical level (Landon, 1991; EthioSIS, 2014).

6.3.3. Total Nitrogen

Total Nitrogen embraces the quantity of N present inorganic forms and the organic compounds in the soil environments (FAO, 2008). The mean soil total nitrogen shows a statistically significant differences

(F=42.805, p = 0.000) among the three LULC types in the watershed. The value ranges from 0.19 % under cultivated land to 0.26% 26% and 0.36% in shrub lands and grasslands, respectively (Table 6.2). The observable low level of total N in the cultivated lands might be ascribed to the low level of soil organic matter pools and Nitrogen tied up in it. Moreover, the low application of nitrogen containing chemical fertilizer, manures and crop residues might contributed to the low level of total nitrogen in the cultivated lands. In the watershed, it is not uncommon to use crop residues for livestock feed, fuel and thatching purposes (example Sorghum stalk in the *Weyna Dega* zone and barely stalk in *Wurch* areas). Similarly, animal dung and wastes have commonly been used for fuel. These might contribute to deficiency of organic matter in the soil and associated decline of total nitrogen in the soil of the watershed.

The analysis also highlights important contrasts across agro-ecologies, suggesting the need for agro-ecology based specific land management practice. From agro-ecology perspectives, the relatively lowest and highest values of total nitrogen were recorded in *Wurch* zone (0.23%) and *Weyna-Dega* zone (0.27%), respectively (Table 6.1). Nevertheless, the ANOVA result revealed that this variation was not significantly ($P \leq 0.05$) significant.

As per the very general ratings stated by Landon (1991), the total nitrogen contents of the watershed soils fall under low to medium categories, calling for replacement and maintenance effort to increase its low status. This implies that nitrogen might be the limiting plant nutrients, particularly in cultivated lands of the study area and increasing productivity without application of organic matter and nitrogen containing fertilizers will be difficult. In agreement with this work, several authors elsewhere indicated that Ethiopian soils particularly in cultivated lands have insufficient total nitrogen due to high leaching lose, crop removal, loss of organic materials and inadequate application of nitrogen fertilizers (Solomon *et al.*, 2002).

6.3.4. Available phosphorus

Despite available phosphorous of the study watershed did not confirm statistically significant difference at $P < 0.05$ (Table 6.1), variations noticed both among land use types and agro-ecologies. For instance, the mean value of available phosphorous ranged from 6.62 ppm in *Wurch* zone to 10.99 ppm in soils of *Dega* zone. Similarly, the high level of available phosphorous (10.87 ppm) was recorded in the cultivated lands while the lowest was recorded in soils of grasslands. The highest mean value for cultivated lands probably linked to the mineral weathering and the residual effect of Phosphorous containing fertilizer (DAP) applied on cultivated lands while the lowest phosphorus content for grasslands might be attributed to higher uptakes by the grasses and/or immobilization by microbes in the litter layers of grasslands (Bewket and Stroosnijder, 2003; Biro et al., 2011).

As per available Phosphorous rating of Ethisis (2014), the overall available phosphorus content of soils of the Watershed were very low, as it was found below 15 ppm. The result agrees with the finding of Murphy (1968), Tekalign*et al*. (2002), Abebe and Endalkachew (2012) who reported low availability of Phosphorous content in most of Ethiopian soils.

6.3.5. Cation exchange capacity and Basic exchangeable cations

The cation exchange capacity (CEC) is total number of exchangeable cations a soil can hold at a given pH value. CEC of soil depends on the relative amounts and type of clay minerals and organic matter content (Montecillo, 1983; Brady and Weil, 2002). The Cation exchange capacity (CEC) of the soils varies across LULC types in the watershed (Table 6.1). The grasslands and shrub lands had significantly higher CEC (mean = 47.27& 47.3 $Cmol_ckg^{-1}$, respectively) than cultivated lands (mean = 43.82 $Cmol_ckg^{-1}$). These difference in CEC was statistically significant ($F=16.473$, $p = 0.004$), suggesting variations in soils pH are explained by LULC types and change in LULC types in the watershed has resulted in the corresponding change in these soil properties.

Based on FAO's (2006b) soil fertility management rating, the cation exchangeable capacity of soil in the watershed is found to be low, suggesting that soils of the watershed seem relatively poor in nutrient reserves for crop production. This could most likely be due to soil erosion, improper farming practices, and complete/partial removal of crop residues that might have contributed to depletion of many of important soils nutrients. In line with this finding, Alemayehu (2007) and Fentaw and Abdu (2011) have reported that *Weyna Dega* CEC of soils in intensive cultivation soils.

Considering mean exchangeable potassium (K) content, the highest (0.78me/100 g) and the lowest (0.33me/100 g) were recorded at the grassland and land units employed for cultivatation purpose respectively (Table 6.1), representing from medium to high content of available potassium. The relatively low exchangeable K was registered in cultivated lands across agro-ecologies. The lower available exchangeable K cation under cultivated land is an indicative for the depletion of the surface soils of the study area probably due to erosion, continuous crop harvest and leaching. The relatively higher amount of exchangeable potassium in the grassland could be attributed to the supply potassium from mineral weathering of the parent materials. However, this variation was not significantly significant (at $p < 0{\cdot}05$) across the three LULC classes and the three agro-ecologies.

As far as exchangeable Na is concerned, the relatively highest (0.31 $Cmol_ckg^{-1}$) and lowest (0.21 $Cmol_ckg^{-1}$) was recorded under cultivated land and grasslands respectively (Table 6.2).Based on the rating suggested by Landon (1991), the contents of exchangeable Na in the watershed was low and cannot cause alkalinity or sodicity problems.

Pertaining to exchangeable Ca content of soils in the study area, relatively higher value (33.91 $Cmol_ckg^{-1}$) was recorded in soil of shrub lands where as the lowest (28.15 $Cmol_ckg^{-1}$) was registered in grasslands and the difference was statistically significant ($F=5.717$, $p = 0.041$) (Table 6.1). This result is in concord with Gebeyaw (2007) who noted the significant effect of land use on exchangeable calcium values. From soil fertility perspectives, a critical concentration of above 30 exchangeable Ca is required for tropical soils (Landon, 2014). Accordingly, the results of this study indicate that soils under all land units had more Ca concentrations than the critical level. This implies that exchangeable Ca is not a limiting factor in the soils of the study area and the soils in the watershed would not require an application of Ca fertilizer as an external input.

Similarly, the lowest (8.71 me/100 g) and highest (12.24me/100 g) mean value of exchangeable Mg were recorded in soils of shrub lands and grasslands, respectively and this difference was statistically significant ($F=26.226$, $p = 0.001$). On the whole, concentrations of Mg in all the land use types of the watershed was rated as medium in reference to the critical level recommended of Ethisis (2014). This implies that responses for the addition of Mg as an external input in the form of fertilizer is plausible in the watershed.

Summary

This chapter evaluated the effects of LULC types and Agro-ecologies on selected physicochemical properties in surface soils (0-20 cm). The findings have indicated that both land use/cover types and Agro-ecologies had significant impact on certain physico-chemicalproperties of soil in the watershed. Agro-ecology was statistically significant for sand, clay and soil pH properties while LULC types were statistically significant for organic matter content, total nitrogen, CEC, exchangeable calcium, and exchangeable magnesium, suggesting LULC dynamics has resulted in the corresponding change in these soil properties in the study watershed.

In conclusion, change in LULC and variations in altitudes influences some soil properties and the results concur with similar studies in Ethiopia and elsewhere. Therefore, any SLM interventions should be location-specific considering both LULC types and agro-ecologies. However, it should not also be undermined the impacts of local lithology and other related soil forming factors on the variation of soil properties.

CHAPTER SEVEN

7. Present scenario and future Prospects of sustainable land management in Gedalas watershed

7.1 Introduction

Land degradation has been, and still, regarded as multi-faceted and complex socio-economic and environmental problems in the highlands of Ethiopia which is manifested with depletion of water, soil and other natural resource; disruption of ecosystem functions, processes, integrity, and services. It is especially severe in Gedalas watershed of the Blue Nile Basin, Northeaster highlands of Ethiopia. Given its particular vulnerability, the idea of sustainable land management through the watershed development program has been initiated with the objective of reducing land degradation risks and ensuring food security at both the nationwide and local levels. To this end, watershed management activities had been in operation since the mid-1970s. Recently, the concept of SLM through Integrated Watershed Management (IWM) approach has emerged to make land resources management more viable. With this broader context in mind, this chapter discusses the most commonly used land management technologies, implementation approaches, factors which influence farm level implementation efforts and sustainability prospects and evaluates its implication on the environmental integrities and the local livelihoods at Gedalas watershed.

7.2. Sustainable Land Management (SLM) Practices in Gedalas watershed

7.2.1 A policy provisions and Ground Realities

Sustainable land management is a major challenge in Ethiopia. The problem is great in areas where land degradation, frequent drought, and the risks of production failure and food insecurity are high, such as in Gedalas watershed. In recent years, several environmental and natural resources management policies and legislative framework which stems from the existing constitution has increasingly been developed, adopted and extensively encouraged to combat the problem of land degradation in the country. These policies, proclamations and strategies entails for optimal and sustainable use of land resources through community based participatory approach. As noted from document review, some of these policies and strategies relevant to the environment and natural resources management include: the Agricultural Development Led Industrialization (ADLI) policy, the Conservation Strategy of Ethiopia (CSE), the environmental law of Ethiopia, the Forestry Action Plan (EFAP), the three subsequent poverty reduction plans (Sustainable Development Plan to Reduce Poverty (SDPRP), the National Population Policy (NPP), the National Food Security Strategy (NFSS), the forest policy among others (FDRE, 2012), Plan for Accelerated and Sustainable Development to End Poverty (PASDEP) and Growth and Transformation Plan (GTPI & II) to mention but a few. The goal of these policies, strategies and plans is to promote all national efforts towards the efficient, equitable, and optimum utilization of the available natural resources for significant socio-economic development on sustainable basis. Furthermore, natural resources management related Proclamation was issued by the federal and regional governments of the country.

These initiatives have been underpinned by a philosophy of community participation with claims that they are empowering land users and local communities to deal with the evils of land degradation. One of the specific proclamations relevant for SLM is the Federal Rural Land Administration and Use Proclamation **(No. 456/2005).**This proclamation demonstrates the Government's concern about land degradation and its commitment to combating the problem. Most importantly the proclamations define environmental protection, farmer's land use obligations, and land use restrictions. It further states failure to protect the land shall lead to loss of his/her use right (Art. 10:1 of Proclamation No. 456/2005).

Free grazing in areas with SWC structures is prohibited and prescribes appropriate SWC structures for all land categories of <30% slope. Bench terraces are mandatory to cultivate lands with slopes of 31 - 60%. The Federal Rural Land Administration and Use Proclamation points out that land with slopes categories of above 60% cannot be used for either cultivation or free grazing. When degraded lands are set-aside for area closure, compensation must be given for prior users. It also specifies a minimum land holding size land user though it left the details for the regional states. Similarly, the Revised Amhara National Regional State Rural Land Administration and Use Proclamation issued in 2006 (Art. 20:1a-h, of Proclamation No. 133/2006), also set obligations to insist on the land users to properly manage the land and preventing all forms of land degradation under their holding.

The recent proclamation issued by the Amhara National Regional State (Proclamation No. 204/2013) stipulates an active involvement of the local community in the implementation of the integrated development; starting from watershed selection, preparation of planning and its implementation; as well as, by any activity done in the watershed region (ANRS, proclamation No. 204/2013, article 8 sub-articles 4). Moreover, to realize policy objectives, an enabling environment, detailing principles and implementation guidelines were established. In this instance, the Community Based Participatory Watershed Development Guideline (2005) proved to be a landmark in the evolution of the participatory approaches in the Watershed Development programme in Ethiopia. The guidelines spell out, among others, overall objectives, the guiding principles, the planning procedures and key actions that harmonize technologies and approaches to address the land degradation problems in rural areas (Desta et al, 2005). It focuses on the integration of the need of communities and the protection of natural resources in one conceptual approach to sustainability. The guideline acknowledges the importance of promoting watershed development interventions planned with community participations keeping in focus their needs, constraints and opportunities for all levels of watershed management activities. The document also underscores decentralized management strategies and the need for effective institutional frameworks.

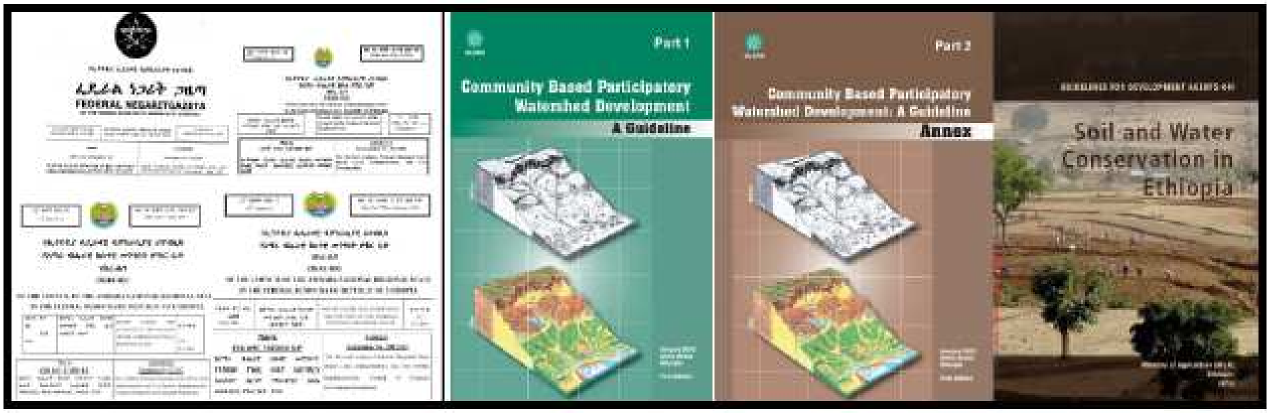


Figure 7. 1: Some of the land management related proclamations and implementation guidelines

Despite these entire imperative legal frameworks, rules, regulations and implementation guidelines, the study results indicate that, in some cases, they are not still optimally implemented and enforced on the ground. To date, SWC activities have only scarcely been integrated in agricultural practice and it is apparent from field that some of the structures are intentionally removed from the farm. Hence, soil erosion damages are still observed on a regular basis. Furthermore, at present no effective and sustainable legal measures are taken when some of the aforementioned regulations are disregarded.

7.2.2. SLM Options and practices

Most of SLM interventions are focused narrowly on SWC measures such as cross-slope barriers in the form of terracing and barriers in gullies that spread across agro-ecologies. Other supplementary prevention and/or mitigation technologies such as vegetative, agronomic and soil management practices were also identified (though in limited extent) under implementation to tackle persistent problems of land degradation at both the plot and watershed levels in Gedalas watershed. The largest diversity of these practices was found on SLM program target sites of the watershed.

As per the official documented report of Office of the Agriculture and Rural Development of the district and field observations, physical SWC measures such assoil bunds (level/graded), stone faced soil bunds, Stone bunds with trenches, diversion ditches, stone check dams and gully reshaping, establishment of area closure, and to a limited extent tree planting (e.g. Acacia Saligna and Eucalyptus camaldulensis) and revegetation of degraded and fragile hillside areas have been implement at the watershed level**.**

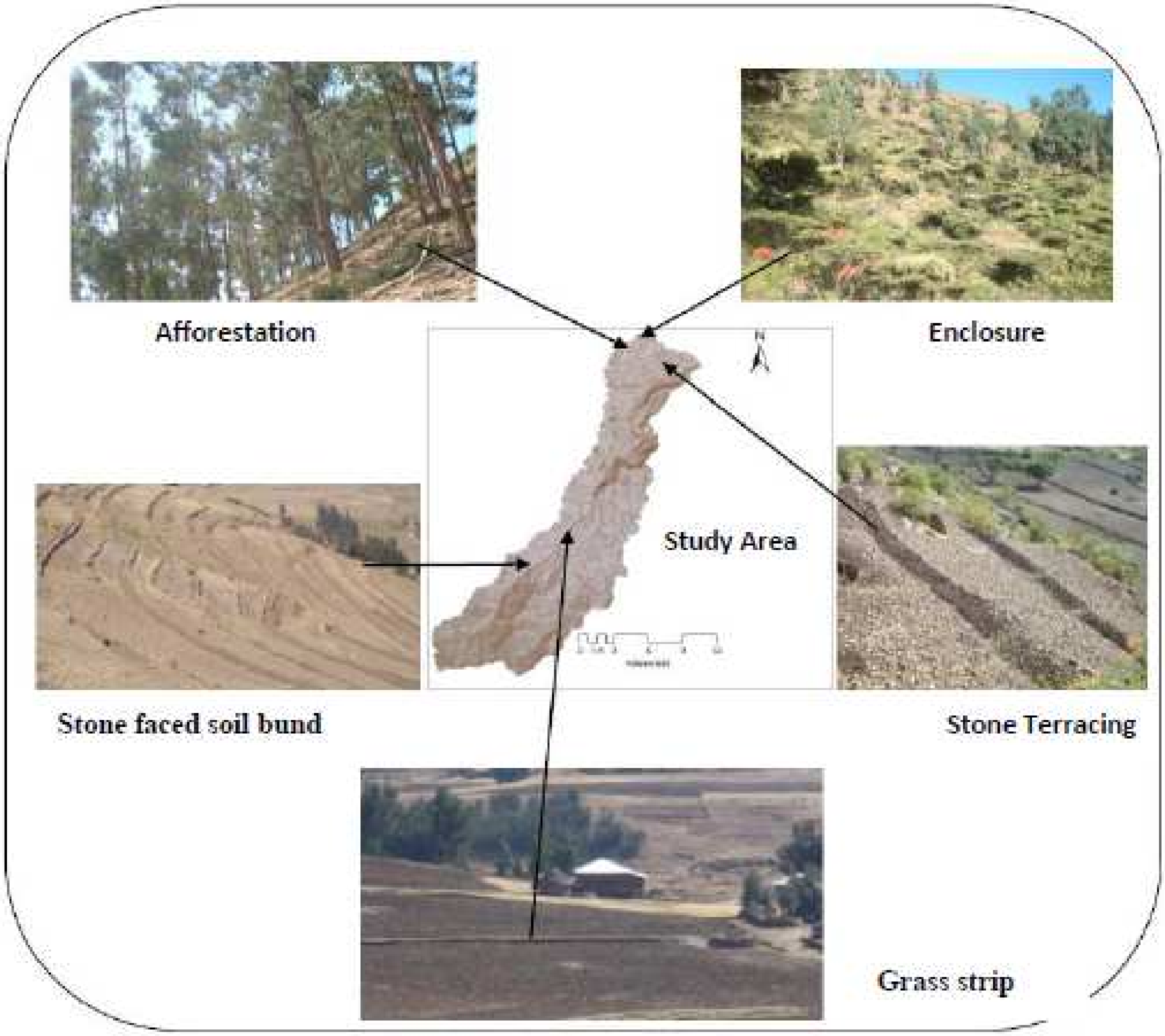


Figure 7. 2: **Examples of SLM practices under implementation in Gedalas watershed (photo: author, 2017)**

Recently, rainwater harvesting and management[14] technologies were introduced as a mitigation strategy against rainfall scarcity in the watershed. A total of 26 rain water/ Runoff Harvesting structures were counted in the watershed in 2017. Most of the structures were found to be earthen, followed by earth dam lined with plastic membrane and cements (Fig.4). The highest proportion of the structures was found in *Weyna-Dega* and *Wurch* agro-ecological zones. Unluckily, wide scale adoption and sustainable use of such technologies were not successful due to several reasons. The information gathered from the household survey in relation to the sustainability challenges of rainwater harvesting and management reveal that inappropriate site selection, poor construction and design, erratic and unreliable rainfall conditions, inter-

[14] In this study, rainwater harvesting and management refers to all acctivities pertaining to collection, storage and efficient utilization of rainwater for crop production or as a source of water for livestock

annual rainfall variability and frequent drought, seepage losses, tearing of plastic parts, frequent silt up of structures, risk of waterborne diseases (e.g. bilharzias/schistosomiasis/ locally known as *alket*), the incidence of injury to kids and livestock were cited as some of the major reasons for its failure. Moreover, due to its space requirements some farmers have not willing to payout part of their land for the construction of the structures which further reduce the size of farmlands. Other problems observed during field visit in a study area were improper utilization (e.g. poor handling, use of the plastics intended to reduce seepage losses for other purposes and frequent damage by animals). As noted from focus group discussion results held on various site of the watershed, the majority of farmers have been discouraged by the loss they incurred on construction of water harvesting structures and have realized that its side effect outweighs the benefits obtained. Generally, the findings of this study highlight rainwater harvesting and management technologies have not been serving the purpose for which it was intended, rather it is a remarkable failure by most of its performance measure in the study area. Thus, there is a need to reconsider the limitations and effectively promote promising rainwater harvesting technologies that takes into account agro-ecologies, socio-economic variations and farmer's knowledge and interests.

Figure 7. 3: **Water storage ponds constructed at different site of the watershed** ***(photo: author, 2017)***

Table 7. 1: Summary of Widely Implemented SLM Practices in Gedalas Watershed (Categories are Based on Liniger et al., 2011)

SLM Measures	Type of SLM technology	Land use types mostly applied on:		
		Hillsides	Cropland	Grazing lands
Structural measures	Stone and stone-faced soil bunds, soil bunds	✓	✓	
	FanyaJuu'	✓	✓	
	Diversion channel/cut off drains		✓	✓
	Gully plugging through check dams	✓	✓	✓
	Moisture harvesting (Trenches, Micro-basin, Eyebrow Basin, Tie-ridging, half-moon terraces),	✓		
Biological measures	hillside closures and enrichment through planting of trees	✓		
	Planting grass and fodder trees (on, below and above bund) for stabilization		✓	
	Grass strips		✓	
Agronomic & soil fertility Management measures	Change in land use types	✓	✓	✓
	Crop rotations involving legume crops		✓	
	Green manuring		✓	
	controlled grazing and resting periods (e.g. during Rainy season)	✓		✓
	Application of organic matter (compost, animal manure, household refuse)		✓	
	Application of chemical fertilizer s (Urea/DAP)		✓	

Source: Tenta District Agriculture office, Focus Group Discussions and Field Observation, 2017

7.2.2.1 SLM practices at the plot level

Respondents were asked to indicate how frequently used each of the SLM practices on their plots. Plots located in *Wurch* and *Dega* agro-ecologies received the most SLM measures compared to plots found in *Weyna-Dega agro*-ecology. The finding reveals that the number of plots that treated with one or more of the SLM measures varied across agro-ecologies. Of the surveyed technologies, use of diversion channels, drainage ditches, and crop rotations involving legume crops were commonly practiced in all agro-ecologies of the watershed.

Green manuring[15] (locally known as '*Wet ploughing*' –as the plot is ploughed immediately after rain season) were mainly practiced in *Wurch* and *Dega* agro ecologies but seldom used in the *Weyna-Dega* areas. Stone terracing/ stone faced soil bunds were commonly practiced to, to shorten slope length and therby decrease soil erosion and to hold soil moisture in the *Weyna-Dega,* lower *Dega*and higher parts of the *Wurch* areas where the slope is very steep and stones are abundant but in a limited extent in the other parts of the watershed. While soil bunds were widely practiced in the upper part of *Dega*& lower section of *Wurch* zones of the watershed where stones are scarce and less so in the other agro-ecologies.

Though in a limited extent, an attempt has been made to stabilize physical SWC conservation structures with grass and fodder trees such as Sesbania sesban trees seedlings and vetiver grass in all parts the watershed. However, discussions with local farmers reveal that accessibility of grasses and trees seedlings restricted their wide scale application in their plots. Moreover, seedling's survival rate and success were very low due to moisture stress and free grazing of livestock (personal communication with DAs, 2017).

Application of chemical fertilizers and the spreading of organic manure were rarely used in the *Wurch* and *Dega*parts of the watershed; however, many farmers in the *Weyna-Dega* used this management practice (though the later confined to homesteads). Although control grazing was common during growing season, this practice was not used very often in any part of the watershed during the dry season. However, a small number of farmers in the SLM project target sites of the *Dega* and *Wurch* zones used this practice. Fallowing was seldom used as a SLM strategy in any of the watershed assessed in the study. This is due to acute scarcity of lands for cultivation.

Application of chemical fertilizer was used frequently in *Weyna-Dega*; however, the practice was used less frequently in the other parts of the watershed. As noted from the focus group participants and key informants, an overwhelming majority of the farmers were not keen to use inorganic fertilizers on their farm because they did not have the cash to buy, and if they had credit, not only the interest rates for loans are high but also they could not guarantee sufficient production to repay their debt as the deadlines for the

[15]Green manuring in this study refers to the ploughing of plots in its wet state before maturity of the weeds and other plants growing on it, which will facilitate easily decomposing process and enhance the level of soil organic matter.

payment of the credit are too short. They were explaining their discontent about forced purchasing of fertilizer through credit, risky loans and expensive price in popular rhyme as reflected in the following local language (Amharic) quotes:

"Yerma Gebeya yishetal Aqmada, Geberiew alike bemadaberia eda", which is literary translated as 'farmers who took chemical fertilizer by credit without their interest, are now deeply suffering from lack of cash to repay debts taken to buy it'.

These explanations imply that farmers of the study area were so far reluctant to use chemical fertilizers as a means to maintain the fertility of the soil and boosting production due to high price of fertilizer and lack of cheap long-term credit for farm development. Hence, the decisions whether or not to use and the likelihood and intensity of use was depending not on ease of access (availability and market distance) but on affordability of the prices of fertilizers.

Yet, the use of inorganic fertilizer has greatly increased year to years regardless of very limited and delayed supplies. In this vein, Amsalu (2015) stated:

"Experiences with technology adoption in Ethiopia indicate that farmers are either reluctant to uptake external recommendations or take some more time to comprehend and implement. Hence, DAs need to spend more time with farmers to properly inform them about technologies and assist them to enhance land productivity"

Agricultural input supply unit coordinator of the district *explains the situation as follows:*

*Three years ago, farmers of the watershed had limited attention for the use of organic fertilizers. Recently, there have been an increasing demand and application efforts of chemical fertilizers on cultivated lands by a number of farmers particularly on the Weyna-Dega and parts of Dega areas of the watershed as it provides rapid returns to their investments usually within one growing season".*Some farmers stated that some croplands do not provide yields without fertilizers.

One *Kebele* chairman living in the watershed expressed more or less the same view:

Initially fertilizer distributions were based on force i.e., farmers were coerced involuntarily to buy and use it. As a consequence, the majority of farmers were reluctant to buy and implement on their plots. He added that, today, a large number of farmers notice the beneft of fertilizer as a means to increase their production and hence are voluntary to use it.

Woreda level statistics of fertilizer distribution for the preceding three years reflected significant increase (Table 7.2). Despite the progress made in fertilizer application technologies, more than $2/3^{rd}$ of chemical fertilizers were distributed to the farmers living in the *Weyna-Dega*and lower parts of *Dega* agro ecological zones of the watershed. This might be due to the fact that farmers living in these parts of the watershed owned relatively small size and limited fertile land compared to those who dwell in *Wurch* and upper *Dega* zones. It was in the best interests of the majority of farmers residing in *Weyna-Dega* and lower parts of *Dega* agro ecological zones to use inorganic fertilizer, because they think failure to do so would ultimately result in the reduction of the productive capacities of their plots and impoverish them.

This result indicates average chemical fertilizer consumption per farming household varies across agro ecologies. The plan also indicates large segments of farmers have intended to apply chemical fertilizer a bite more than the preceding years. However, despite significant increase in fertilizer use, misapplication is common across all agro ecologies as farmers rely on personal judgment. Most existing fertilizer recommendations inform farmers only the amount of fertilizer (kg per hectare) they should apply to their plots. Implementing these blanket recommendations for all agro ecologies, crop and soil types could be wrong.

As it was confirmed from the DAs of respective agro ecologies, the majority of farmers depend on their own interest to manage fertilizers, and sometimes it was difficult to convince them and hence, they apply fertilizers mostly below recommendation levels as their target is to cover all their plots. This implies on-site technical support and field demonstration is still essential for implementation of better fertilizer application practices. Another pertinent problem is the lack of soil fertility data base and absence of site, context and crop specific fertilizer recommendation. The key soil fertility limitations and nutrient shortages that impact on crop yield in the area are not well known. Besides, integrated soil fertility management is limited in the area. This is due to various reasons including: high price of organic fertilizer; lack/limited access to those fertilizers, farmers' constrained knowledge on how to integrate and so on. This highlighted that the recent government efforts to develop area specific soil needs-based fertilizer recommendations and fertilizer blending must be scale up instead of indiscriminately apply the same fertilizer types as 'one-size-fits-all' solutions to all areas, quite irrespective of the soil types, agro-ecological specificities and crop needs.

Table 7. 2: Amount of fertilizers distributed in the watershed (Quintals)

Available Fertilizer type	2015	2016	2017	2019 (plan)
UREA (supplying nitrogen and phosphorus)	230	917.5	1072	1339
Blended Fertilizer (NPSB)	218	977	1148.5	1341
Total	448	1894.5	2220.5	2680

Source: Tenta district Agriculture office, 2018

The table above indicates that fertilizer demand increases by fivefold in 2017 as compared to 2015's data. In other words, the benefits that fertilizer can bring have been apparently well understood by the farmers from time to time. This implies that there is a good prospect for scaling up of chemical fertilizer application and extent of limitations may not renounce farmers from using technology that provides immediate returns for household consumption. This implies, technology that enhances field crop production within a short timeframe could be very promising. Yet, some farmers of the study area donot conceal that the supply and distribution of fertilizer are not transparent.

In addition, indigenous SWC measures such as grass strips (*Weber*), cut-off drains and traditional ditches (locally known as *"Boy")* which are drawn by a pair of oxen are also widely used either to supplement other structures or as an independent measure to protect the arable land from runoff and avoid the problem of water logging. For example, diversion or cut-off drains are laid on the upper sides to protect cultivated lands from runoff flowing down while drainage ditches are constructed every ploughing season usually at the end of ploughing and the ditches are running either vertically or/ and diagonally across the slope of cultivated land thereby to safely drain runoff generated within the cultivated lands and avoid the problem of water logging.

Most farmers frequently state: *'ploughing sloping lands without drainage ditches is unsuccessful".* This opinion from farmers seems to reflect the historical importance of drainage ditches in their farming systems.

Though, there are diverging views concerning the effectiveness of drainage ditches, these practices are still widely used by farmers in almost all agro-ecological zones. Grass strips were widely practiced in *Dega* and *Wurch* agro-ecologies but less in *Weyna-Dega*areas of the watershed. As it was noticed during the fieldwork and assured by key informants, grass-strip was the most popular strategy due to its multiple uses, notably soil conservation; provide forage for livestock feed and grasses for thatching houses. Furthermore, the local community in the area uses it as a boundary to demarcate two or more adjacent plots belonging to different individuals. Some key informants from *Dega* zone stated the potentials of grass strips interestingly as:

> *… of the various ways of SWC measures, grass-strips is one of our number one choice as it is not only well to counteract hazard of soil erosion, but also supply supplementary feed for our cattle, don't need more labor for establishment of new & maintain the old one.*

The explanation highlights the choice of SLM technology is influenced by indigenous knowledge and its multiple benefits.

Table 7. 3: SLM Practices implemented at the plots level (percentages within parenthesis)

Agro ecology	Never use	Use Sometimes	Use always	Score Mean*	SD	F	Sig.
	Application of stone/stone- faced soil Bund						
W/Dega	61(80.3)	8(10.5)	7(9.2)	1.29	0.629	11.718	.000
Dega	159(82)	30(15.5)	5(2.6)	1.21	0.465		
Wurch	67(58.8)	33(28.9)	14(12.3)	1.54	0.706		
Total	287(74.7)	71(18.5)	26(6.8)	1.32	0.595		
	Application of soil bunds						
W/Dega	71(93.4)	5(6.6)	0(0.0)	1.07	0.25	27.88	0.000
Dega	97(50)	87(44.8)	10(5.2)	1.55	0.594		
Wurch	85(74.6)	27(23.7)	2(1.8)	1.27	0.485		
Total	253(65.9)	119(31)	12(3.1)	1.37	0.545		
	Use of diversion channel/cut off drains						
W/Dega	7(9.2)	45(59.2)	24(31.6)	2.22	0.602	7.055	0.001
Dega	39(20.1)	87(44.8)	68(35.1)	2.15	0.729		
Wurch	40(35.1)	48(42.1)	26(22.8)	1.88	0.754		
Total	86(22.4)	180(46.9)	118(30.7)	2.08	0.725		
	Planting grass and fodder trees for Stabilization of structures						
W/Dega	58(76.3)	15(19.7)	3(3.9)	1.28	0.532	0.111	0.895
Dega	152(78.4)	31(16)	11(5.3)	1.27	0.56		
Wurch	91(79.8)	18(15.8)	5(4.4)	1.25	0.525		
Total	301(78.4)	64(16.7)	19(4.9)	1.27	0.543		
	Use of grass strips						
W/Dega	62(81.6)	8 (10.5)	6 (7.9)	1.26	0.597	2.318	0.100
Dega	132(68)	37 (19.1)	25(12.9)	1.45	0.713		
Wurch	77(67.5)	21(18.4)	16(14)	1.46	0.731		
Total	271(70.6)	66(17.2)	47(12.2)	1.42	0.699		
	Use of drainage ditches						
W/Dega	34(44.7)	13(17.1)	29(38.2)	1.93	0.914	0.664	0.515
Dega	66(34.0)	49(25.3)	79(40.7)	2.07	0.864		
Wurch	38(33.3)	32(28.1)	44(38.6)	2.05	0.85		
Total	138(35.9)	94(24.5)	152(39.6)	2.04	0.869		
	Controlled free grazing						
W/Dega	70(92.1)	6(7.9)	0(0.0)	1.08	0.271	13.649	.000
Dega	121(62.4)	65(33.5)	8(4.1)	1.42	0.572		
Wurch	67(58.8)	43(37.7)	4(3.5)	1.45	0.566		
Total	52(67.2)	114(29.7)	12(3.1)	1.36	0.542		
	Crop rotations involving legume crops						
W/Dega	42(55.3)	28(36.8)	6(7.9)	1.53	0.642	1.225	0.295
Dega	128(66)	51(26.3)	15(7.7)	1.42	0.632		
Wurch	67(58.8)	35(30.7)	12(10.5)	1.52	0.681		
Total	37(61.7)	114(29.7)	33(8.6)	1.47	0.65		
	Green manuring						
W/Dega	76(100)	0(0.0)	0(0.0)	1	0	31.822	0.000
Dega	34(69.1)	55(28.4)	5(2.6)	1.34	0.525		
Wurch	55(48.2)	49(43)	10(8.8)	1.61	0.647		
Total	265(69)	104(27.1)	15(3.9)	1.35	0.553		
	Application of organic matter (animal manure, household refuse)						
W/Dega	52(68.4)	20(26.3)	4(5.3)	1.37	0.585	7.821	0.000
Dega	68(86.6)	20(10.3)	6(3.1)	1.16	0.448		
Wurch	02(89.5)	11(9.6)	1(9)	1.11	0.346		
Total	22(83.9)	51(13.2)	11(2.9)	1.19	0.46		
	Application of inorganic fertilizer						
W/Dega	32 (42.1)	28(36.8)	16(21.1)	1.79	0.771	23.312	0.000
Dega	148(76.3)	36(18.6)	10(5.1)	1.29	0.557		
Wurch	95(83.3)	12(10.5)	7(6.2)	1.23	0.549		
Total	75(71.6)	76(19.8)	33(8.6)	1.37	0.637		
	Land Use change						
W/Dega	71(93.4)	3(3.9)	2(2.6)	1.09	0.372	0.507	0.603
Dega	177(91.2)	7(3.6)	10(5.2)	1.14	0.473		
Wurch	107(93.9)	3(2.6)	4(3.5)	1.1	0.398		
Total	355(92.4)	13(3.4)	16(4.2)	1.12	0.433		

*weighted 1 through 3 with "never use" receiving a value of 1 and "use always" receiving a value of 3.

To examine the finding presented in Table 7.3 in greater depth, separate analysis of variance statistics was computed for comparisons of respondent index scores for each agro-ecology with each other. *Weyna-Dega* farmers reported significantly less use of SLM practices than farmers within the other two agro-ecologies. There was no significant difference between *Dega* and *Wurch* respondents. This could be due to the intervention of SLM programs in these two agro ecologies.

Table 7. 4: Comparison of SLM practices among agro-ecologies

Agro-ecology	F-Test	Sig. Level
Weyna Dega Versus Dega	31.8	0.001
Weyna Dega Versus Wurch	27.9	0.001
Dega Versus Wurch	2.3	Not Sig.

7.2.3. SLM practices through integrated watershed management approaches

SLM approaches[16] practiced on the ground play the critical role whether the anticipated outcomes are realized and sustainability achieved (Dyer et al., 2014). For the last few decades, various implementation approaches have been followed to promote the SLM practices in the highlands of Ethiopia in general and Gedalas watershed in particular including Food-for-Work program (1972to 2002), MERET project (2003–2015), PSNP (2005–present), Community based campaign through annual free-labor days (1998–present), and the National SLM Project (2008–present) (Haregeweyn et al., 2015). However, most of these approaches have been 'top-down' ("Command instead of comment approach" approach) which were criticized for their lack of sufficient consultation with local communities, problems in design and implementation, disregard of indigenous knowledge of the land users and insufficient technical support and financing for local implementation costs.

As it has been indicated in the 'SLM techniques and approaches in Ethiopia' document (MoARD, 2010), integrated watershed management approaches denote the implementation of SLM technologies on a participatory bases following integrated watershed management principles. The overall objectives of SLM through integrated watershed management approach is to make best use of the land and water resources in the target watershed and thereby to achieve the triple objectives of environmental sustainability, economic growth and social equity.

An attempt was made to assess the implementation of SLM technologies on the study watershed. Though SLM Program pilot sites has tried a lot to accommodate both expert knowledge and community experiences towards promoting sustainable land management, the top down and rigid government

[16]Approaches in this study refer to the ways and means to promote, support and implement one or several SLM technologies in the watershed.

extension and decision-making approach are still apparent in the watershed. The planning task and decision-making are made at the regional government level and then passes through the *zone*, and *Woreda* then reaches the *Kebele, sub Kebele* and the local people for implementation.

As noted from the study, the district promotes sustainable land management technologies based on the direction of the Zone, develop action plans for the *Kebeles*, and enforce its implementation (mostly with coercive and punitive approaches) through annual community free labor contribution campaigns organized by local government (*Kebele* administration) and development agents in all *kebeles* irrespective of agro ecological setups. The rural command post, the watershed development committee and "One to Five work teams" were responsible for implementation. Since such implementation approaches did not reflect local context, constraints and the preference of the local community, communities' commitments are often not in place and far from expectations. In view of these challenges, the sustainability prospects of SLM activities and campaigns are questionable. This implies that top-down planning and directives are still in place which negatively affect local level planning and priority setting.

Nevertheless, farmers of SLM Program pilot sites seem successful at least to the lifespan of the program. The success of the intervention is attributed to the fact that the program attempts to address farmers' priority needs including SWC measures, management of drinking water, plantation of highland fruit trees, introduction of improved crop varieties, and livestock feed, promotion of good sanitation practices (e.g., toilet room construction) and other related activities through community engagement and consistently followed up on the activities.

Annual community free labor contribution approach has also been implemented for the last few years in the watershed. Farmers were asked about their initiatives, perceived benefits and challenges of an annual free labor contribution for watershed management activities in their respective localities. The majority of the respondents acknowledged annual free labor contribution as a good idea for restoring degraded lands which might not be done at individual level. Nonetheless, they do not feel comfort the timing and number of working days. As they further argued, since the time arranged for free labor contribution overlaps with farming activities and the working days are too long, most farmers are not willing to participate. This clearly implies that the time frame and the wider interests of community for the time of work should be reconsidered.

PSNP is another approach for the implementation of SLM practices in the watershed. Since the study watershed is one of the food insecure areas in Ethiopia, PSNP was implemented to chronically food insecure households. Support to those households have been delivered through two ways vis-à-vis public works which provides payment in return to labour intensive public works and direct support which delivers unconditional grants to the labor-poor, elderly and disabled households ((MoARD, 2014). PSNP approaches was anticipated to protect household asset deterioration and promote invest in SLM practices such as SWC activities; for which they received payments in cash or in kind (Anderson et al., 2011). However, participating households claim a lot of works imposed on them as the *kebeles* look forward to accomplish activity such as road building, terracing, caring cements and other construction materials etc whenever necessary. Hence, the majority of safety net program participants nicknamed themselves as "*Donkey of the Kebele*" to sum up their discomfort on the burden of tasks imposed on them. This implies those groups who were benefited from safety net program because of labor work are being highly discouraged.

In connection with this, one research participant, who was in his mid-forties, stated his dissatisfaction as follows:

> *When a farmer wants to pull his pack animals (Horse/donkey/ mule), he first approached by showing some grains spread on a container. Since these animals attracted in the grains, he can realize his objectives. This is similar to PSNP approaches of the government. The government not only gives us ('beneficiary' farmers) a small amount of incentives (in kind or in cash) for the huge labor work we did but also call always us to accomplish any task required by the Kebele.*

Focus group discussion and field observation has also confirmed this fact. This implies approaches to effectively implement the SLM programs in the watershed needs reconsideration.

7.2.4. Level of institutional support on SLM practices: From farmer's perspective

To check level of institutional support on the ongoing SLM practices, farmers were asked to rate their perception and experiences about the capacity building and training issues, incentives provided for promotion of the program, clarity on the policy, rules and bylaws, technical support and advice rendered, and other related based on a 3-point scale vis-à-vis not at all (1), sometimes (2) and always (3). Results are summarized and depcited in the table below.

Table 7. 5: The Level of institutional support on SLM (Mean of respondents on 3-point likert scale)

Actions/ Activities	Agro-ecology			F Value	P value
	W/Dega	Dega	Wurch		
Hold community meetings to raise awareness on SLM issues	1.46	1.52	1.55	0.714	0.490
Work with local communities, consult & integrate local knowledge to identify and prioritize for SLM intervention	1.37	1.7	1.71	11.747	0.000
Provision of reasonable incentives for promotion of SLM practices	1.68	1.72	1.83	1.491	0.226
Support on formulation & Clarity of community bye-laws	1.58	2.15	2.07	16.592	0.000
Technical support and advice on SLM programs	1.62	2.28	2.15	18.363	0.000
Set up demonstration plots to promote SLM practices	1.58	1.95	1.97	6.372	0.002
Assess capacity gaps and provide consultation, facilitate training, experience-sharing visits and capacity building as deemed necessary	1.33	1.47	1.52	2.529	0.081
Training on existing government policy, legislation, proclamations and enforcing procedures to the community	1.62	2.03	1.85	10.976	0.000

Source: Field survey 2017

As shown from the table, the result on the mean perception score for all action indicates, it is relatively lowest for *Weyna-Dega* agro-ecology as compared to others. The disparity could be attributed to the fact that most of the sub watersheds in *Dega* and *Wurch* agro ecologies are the target sites for SLM program. That is probably why the mean perception scores are relatively larger for*Dega* and *Wurch* agro-ecologies for all stated parameters despite the scores are still low. Comparison using one-way ANOVA also confirms the existence of significance mean difference on most actions and the variation was significant at 1% probability level. However, it was also attested non-significant mean score differences in perceptions scores pertaining to awareness raising meeting, incentives for promotion of SLM practices and training on policy related issues.

7.2.5. Implementation of SWC Activities in the watershed

7.2.5.1. Standard specifications and actual implementations

An attempt was made to assess the technical qualities of three different structural SWC measures (Stone bunds, soil bunds & stone-faced soil bunds), since these are the most often implemented conservation structures in the watershed. Physical SWC structures implemented at croplands through mass-community mobilization program since 2010 was considered for assessment. Hence, the age of the structures varied from 7 years to structures which were under construction during field measurements. The base year was selected because the Amhara national regional State has intensively launched SWC activities through public campaign since 2010. The evaluation was carried out through direct field observations and measurements on the randomly selected structures which were commonly installed at croplands. Assessment was conducted on the technical fitness of space between successive bunds, vertical intervals of the structures, effectiveness and compatibility to the farming activities vis-à-vis the Community Based Participatory Watershed Development Guidelines (Desta et al, 2005).

Table 7. 6: Standard specifications and actual implementations of SWC structures

Type of SWC structures	Specifications				
	Slope (%)	VI (m)		Distance (m)	
		Design Recommendation	Actual average field measurement	Design Recommendation	Actual average field measurement
Soil bund	3-8	1-1.5	2.5	50 - 12.5	53.5
	8-15	1-2.0	2.5	25 - 6.7	30.5
	15-20	1.5-2.5	5	16.67 - 7.5	21
Stone bund and Stone-faced soil bund	5	1	2.5	20	29
	10	1.5	3	15	20.5
	15	2.2	5.5	12	15.5
	20	2.4	8	10	15
	25-50	2.5-2.8	7	4	12.5

Source: Field measurement & adapted from Watershed Development Guidelines by Desta et al (2005)

Accordingly, around thirty (old and new bunds) randomly selected structures in cultivated land (ten cultivated lands from each agro-ecology) were assessed to evaluate the technical quality of constructed physical SWC structures. The minimum distance between two consecutive bunds was found to be 12.5 m and the maximum distance was 65 meters. Out of the total 30 evaluated structures only 14 (47%) structures were established based on the recommend specifications as indicated in the national guidelines (Table 7.8).Though better construction quality and maintenance of SWC structures were observed, particularly on the *Wurch* and upper parts of *Dega* agro ecological zones where SLM program under operation, the majority of structures constructed on the other parts of the watershed were below the recommended technical standards. The space between successive bunds and vertical intervals were significantly wider than the recommended national standards. The problem was serious mainly on the *Weyna-Dega* areas, where there is steep slope topography and shortage of farm lands.

According to the expalanation of DAs, one of the main reasons for the failure to maintain recommended SWC structures was that most farmers did not prefer at least narrow spacing as they perceived not only inconvenient during plowing activities and occupy much farmlands but also the establishment of structures needs more labor (e.g. soil is too hard to dig & stones are absent or needs to be transported from other sites). Hence, wide spacing structures were built to respect local communities' interest. Focused Group Discussants and key informants drawn from the community revealed on their part, the main reasons for the establishment of wider space bunds were lack of sufficient technical support and follow up from DA's during bund design, layout and actual implementation. Similar to previous studies (e.g. Bekele and Drake, 2003; Tefera and Sterk, 2010; Dessie et al., 2011), this finding points out that lack of technical support from DAs negatively influences farmers' cooperation and technology adoption behavior. Field visits on the entire watershed also indicated that though SLM Project sites have been implementing relatively better SWC structures (as compared to others), the space between successive structures built on the croplands of other sites across the watershed were meaningfully found to be wider than the recommended standards.

The survey conducted revealed that, since the space between consecutive structures and the vertical interval of most structures in the watershed were lower than national standard, it could not efficiently arrest soil erosion problems; instead, promote surface run off and damage of bunds as well as croplands through accumulation of water in the bunds. Due to this fact many farmers particularly in the *Weyna-Dega areas* create drainage ditches (locally known as '*boy*' randomly within the structures to protect the plot from runoff damage during heavy storms. The finding concurs with similar reports of and Dimtsu, (2018) in northeastern Ethiopia, Walie (2016) and Molla and Sisheber (2017) in Northwestern Ethiopia and Bekele et al., (2018) in southern Ethiopia.

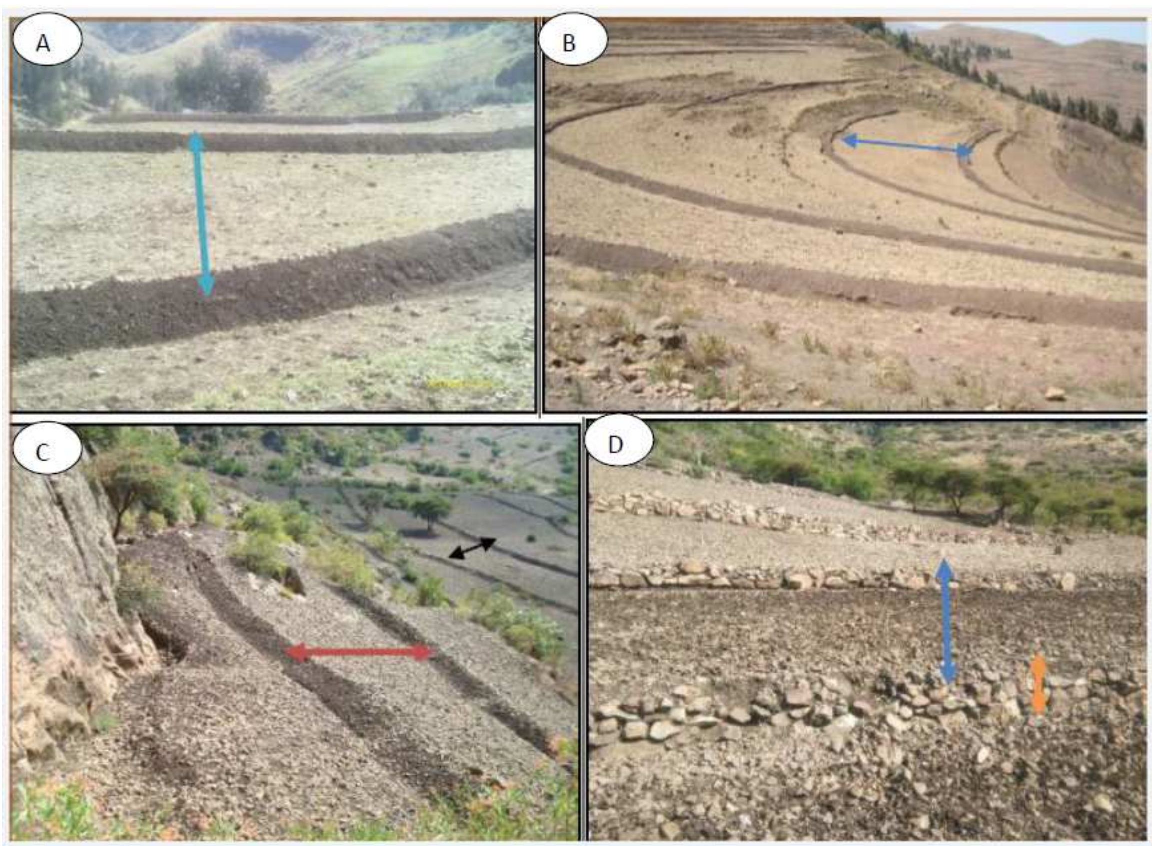


Figure 7. 4: SWC structures on croplands; A= Soil bunds; B & C= stone faced soil bunds; D= stone terraces with sign of destruction (Gedalas watershed, Feb, 2016).

7.2.5.2. Farmers' View on the Qualities of SWC Structures

As the direct observers, farmers were asked on the perceived quality of SWC structures installed in their localities. Diverging and converging views were noted from farmer's response. The view of those who resides at SLM pilot sites (*Wurch* and upper *Dega* areas) where slightly different from those who dwell in *Kolla* and lower *Dega* areas. In the case of the former, the majority of respondents rated the quality and efficiency of SWC structures from medium to good, while those who live in other parts of the watershed rated structures as low quality.

During the discussions made with focus group participants and key informant, farmers were asked the reasons for the construction of low qualities of SWC structures. As expected, most of the participants enumerate farmer's lack of adequate training for design and layout of the structures; use of traditional measuring device such as yardstick during construction and the focus was given to quantity (i.e., size of area covered with bund) rather than technical quality and sustainability of the structures. Moreover, execution was quota based rather than demand driven approaches, which makes intended role of SWC less effective, inefficient and unsustainable.

Farmers were also asked to evaluate the benefits of the respective SWC technologies in their localities. While the majority of farmers do have great appreciation for the various benefits of the SWC structures, a few were less passionate. In line with SWC literatures, grass strip were the preferred conservation structures as reported by the majority of farmers. This is because grass strip not only minimize soil erosion but also provide grass for livestock feed and prevent seeds and fertilizers from being washed away during heavy rainfall events.

During field visit of survey period, it was noted that though maintenance and attempt of stabilization of SWC structures were relatively attempted at SLM program target sites (as compared to others), most stone/soil bund structures were silted up and partially or totally damaged on both communal land and croplands of the watershed due to overflow and improper tillage practice along underside the bunds. Lack of close supervision and quality control system, habit of free livestock grazing & roaming of wild life (e.g. monkey) were the main reasons observed for the failure of the SWC structures. Moreover, with the exception of few in the SLM program pilot sites *(Wurch* and *Dega* zones); structures established elsewhere at the watershed were not supported with biological conservation measures. Likewise, some areas designated as closed to man and animals seems under pressure from the local community living in the vicinity.

Figure 7. 5: **wholly or partially destroyed SWC structures in different sites of the watershed**
Source: Field survey (photo: author, 2016)

Though the majority of the respondents did not show efforts to do maintenance work and protect the SWC structures from destructions, during field observation, it was found that there were some devoted farmers who show unreserved and exemplary activities on managing SWC measures installed on their farmlands. This signals a clear message that the maintenance of SWC structures was poor and stabilization of structures with biological measures were inadequate in the study watershed despite the strong rhetoric in both regional and national land use and adminstartion procliamations and implementation guidelines.

Acceptance and usage of recommended technologies depends on the perceived usefulness and perceived ease of use. In this regard, farmers were asked detailed questions to give their experiences on the potentials of selected major SWC measures established on their cultivated lands to reduce soil erosion, improve productivity, and maintain soil moisture and other similar issues. The results highlight that perceived effectiveness to control soil erosion, improve productivity, retain soil moisture and perceived ease of use and durability are key indicators for adoption and sustainability of SLM technologies and management practices. The overall farmer's responses are summarized in the figure 7.6. below.

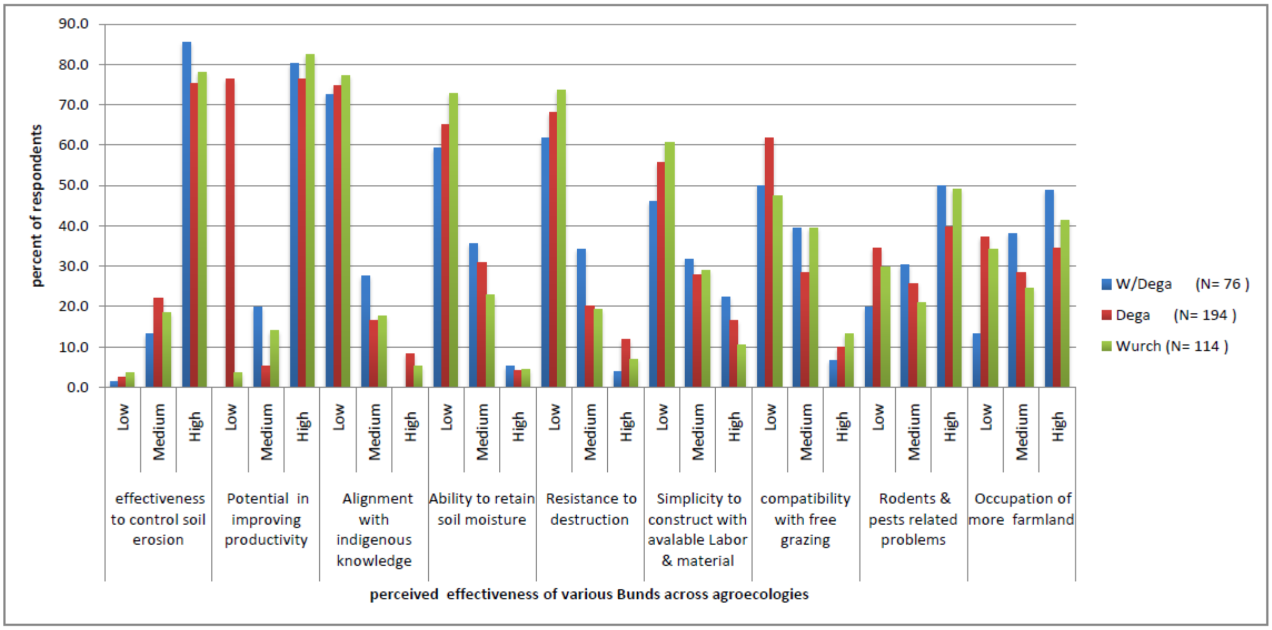
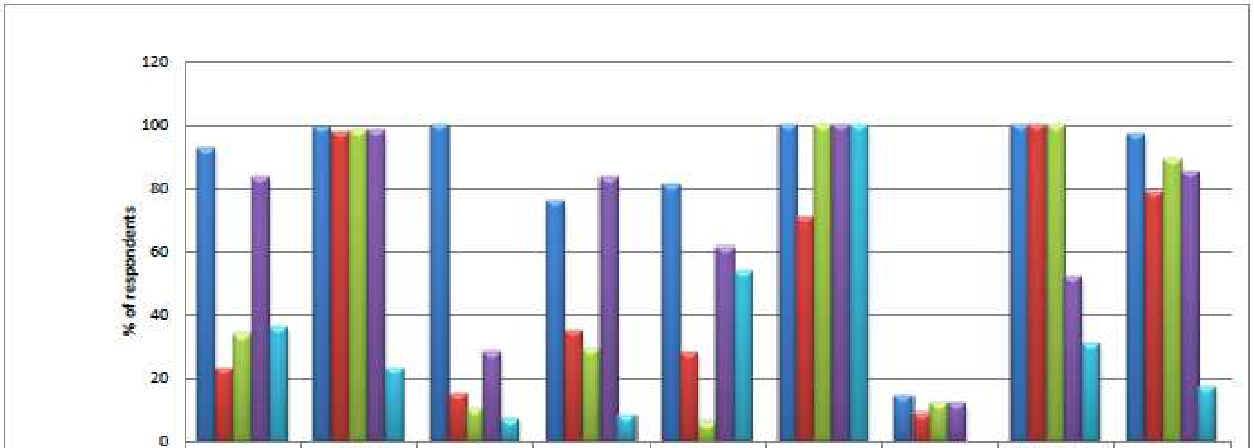


Figure 7. 6: Efficiency of SWC structures from farmers perspective

Farmers were also asked to give their views on the limitation of these SWC structurs. The most frequently cited limitations by the respondents include problem during ox ploughing, incompatibility with free grazing, loss of cultivable land, high labor requirements for their establishment, create favorable conditions for dissemination of running grass, harbors rodents and aggravate the intensity of soil erosion when damaged, to mention but a few (Fig. 7.7). During the focus group discussion, farmers *s*hared similar undesirable side effects, amongst these are high labor requirements for establishing and maintaining structures, the loss of cultivable area, lack of tangible benefits, as well as problem of rodents, weeds, pests, and diseases. Moreover, participants further elucidate the accumulated water behind some structures (e.g. the ditch) caused problem of water-logging. During field visit, the author had got chance to communicate with farmers who were constructing stone bunds through community free labor campaign work. During informal discussions, an overwhelming majority of the farmers from the *Wurch* zone forwarded their discontent and worry on the problem of rodents associated with the bunds through jock as "*we are constructing house to reproduce rodents.*" This implies that even though terraces are important to reduce soil erosion, this would not be a guarantee to be adopted, as other factors may daunt farmers from acceptance and sustained use of it.



perceived constraints	Not convenient for ploughing	Labor intensive for establishment and maintenance	Hiding and Breeding of rodents/pests	Input constraints for establishment	Encourage weed infestation & dissemination	Reduce arable land for crop production	Lack of knowledge to implement	Aggravate the problem of soil erosion when damaged	Frequent destruction of structures by cattle
Stone /soil bunds	92.8	99.2	100	76	81.3	100	14	100	97
Cut off drains	23	97.4	15	35	28	71	9	100	79
Water ways	34	98.2	10	29	6	100	12	100	89
Fanya Juu	83.3	98.3	28.3	83.3	61.5	100	11.7	52	85
Grass strip	36	23	7	8	54	100	0	31	17

Figure 7. 7: **Constraints impeding implementation and sustained use of physical SWC structures as perceived by farmers in Gedalas Watershed** (N=384)

7.2.6 Level of community participation in SLM practices: Rhetoric and realities

Participation of local community as a key dimension for the successful implementation land management has recently been emerged as new paradigm since its endorsement at the Rio Conference in 1992. In this context, most of the natural resources' management documents in Ethiopia, from the constitution to the strategic documents, dealt with the issue of participation in environmental resources management and conservation. For instance, article 92 (3) of the current constitution of Ethiopia states: "*People have the right to full consultation and to the expression of views in the planning and implementation of environmental policies or projects that affect them directly*." As per common guidelines issued by MoARD, Government of Ethiopia, active stakeholder participation has been underlined as an approach for pursuing natural resource management (Desta et al., 2005). This is because stakeholder participation is important for identifying local problems, integrate local knowledge with new technologies and harmonize development objectives with community values and preferences (Rodriguez-Izquierdo et al., 2010; Lyndon, 2011). In addition, it is often implied that community participation results in higher community satisfaction. But in the context of the study area, it seems easier to say than do.

The literature suggests various participation typologies to monitor and evaluate level of community involvement in and their influence on decisions related to development activities that will affect them (Arnstein, 1969; Wandersman, 1981; Pretty, 1995). For example, Pretty (1995) have proposed five ladders of for analysing citizen participation. These include manipulative participation, passive participation, participation by consultation, participation by material incentives and functional participation. For this research, Pretty's ladder (1969) was used to assess level of farmer's involvement and participation in decision making, implementation, monitoring and evaluation, and in sharing the benefits of the SLM programmes from their own perspective across agro-ecology. Despite the overall results shows better community participation implementation activities across agro ecologies, substantial disparity was observed on the level of participation among residents of the three agro ecologies in various stages of SLM practices. This could be due to the presence of consultative and consensus-built meetings, monitoring and evaluation activities by SLM project working in *Wurch & Dega areas* **(**Fig. 7.10).

Figure 7. 8*:* Construction of SWC measures by mobilizing the community through the free-labor day scheme

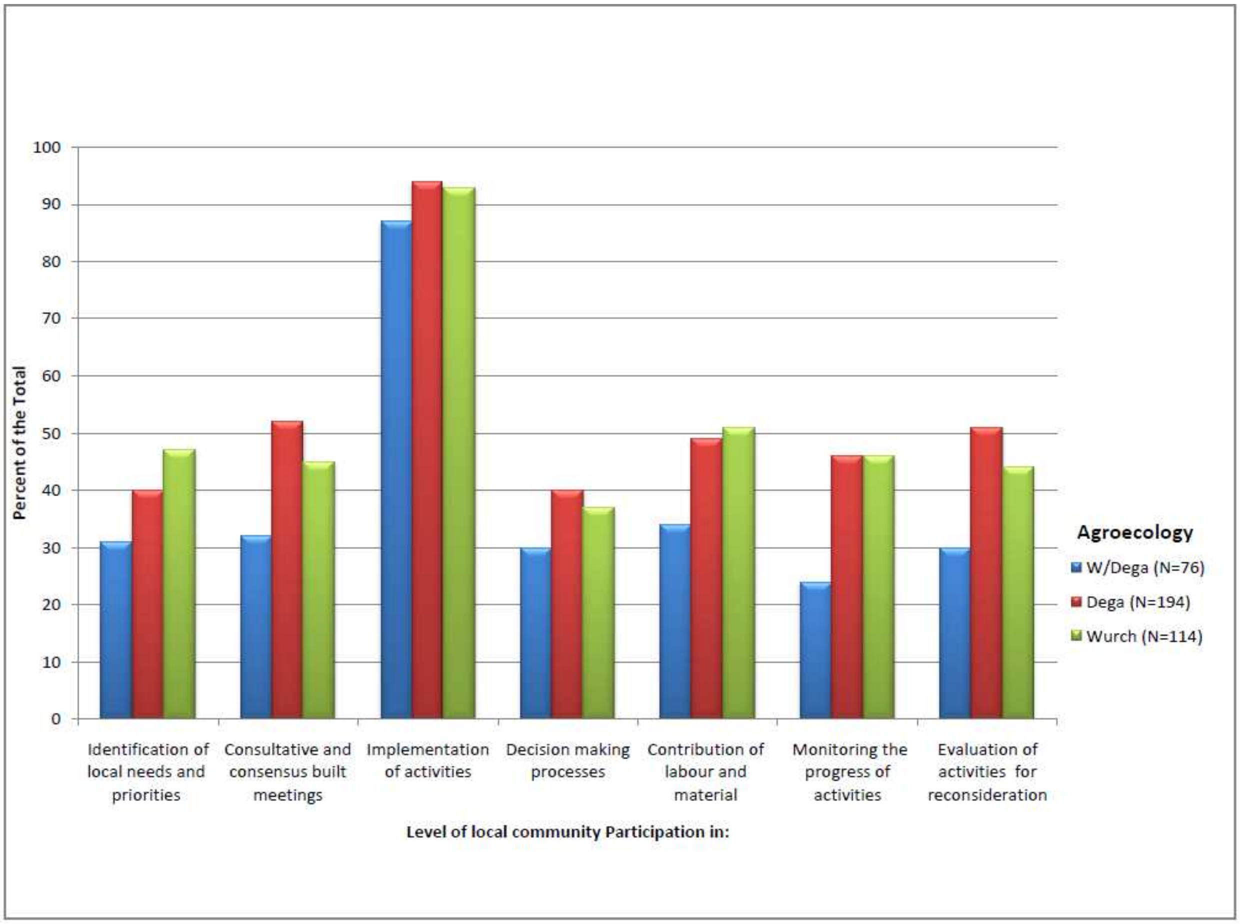


Figure 7. 9: Community participation in SLM activities, 2016/17

The figure above illustrates just under half (46%) of the 76 household respondents in *Weyna Dega*reckoned that they had "sometimes" been involved in identification of local needs and priorities; while just about 31% reported that they were "always" involved, with another 23% reporting that they were "not at all" involved. In contrast, a larger proportion (40%) of respondents among *Dega* reported that they "always" involved in the identification of local needs and priorities. Just over one third (38%) of respondents replied that they had "sometimes" been involved in the identification of local needs and priorities and 22% had "never" been involved at all. In contrast, community members interviewed from *Wurch* areas reported that were either "always" (37%), "sometimes" (47%), or "not at all" (16%) involved identification of local needs and priorities.

Similarly, 32% of household respondents indicated that they had "always" been involved in consultative and consensus-built meetings on issues pertaining to SLM practices; 54% had "sometimes" been involved; 14% had "never" been involved in *Weyna Degaareas*. In *Dega* Areas an overwhelming majority of sample respondents (52%) reported that they had "always" been involved in the consultative and consensus-built meetings. Like in the previous level, in *Wurch* areas, majority (45%) of the household respondents reported to have always attended in the consultative and consensus-built meetings; 44% reported sometimes attend the consultative and consensus built meetings while 19% reported never at all attend the consultative and consensus built meetings.

The overall results of the study indicate that though legal provisions were made, many gaps have been observed between rhetoric of voluntarily participation and realities of the actual execution processes of community participation in all three agro-ecologies of the study watershed.

For example, according to the policy and implementation guidelines, local communities are expected to play a significant role in identify, prioritize, plan and work together with professionals and government planners to solve their local problems instead of implementing predetermined tasks. District and *Kebele* level reports also indicates SLM through watershed approach are planned and implemented based on farmer's interest, local knowledge and the topography and biophysical situation of the area.

One team leader from department of natural resources confidently denied rather than admitting pressurized from public participation by further narrating the process as follows:

> *To convince people and sustain the activities, we are planning with the community; we always involve local community and discuss the issue with them to develop trust and built sense of ownership before actual implementation, which is good for maintenance and sustainability*.

However, the reality apparently deviates on the ground, as the local people participate passively by accepting the prior decisions of the government agents or get information of decisions after meetings. Sometimes, asked for opinions without necessarily to influence prior decisions. This implies that community participation is rhetoric and much of this has remained restricted to mere lip service and tokenism. The work is implemented under the overall planning, order, supervision and guidance of government agencies.

The majority of farmers revealed that there are some local administrative bodies that compel farmers to participate in the programs (e.g. SWC) without their interest. A 45 years informant contested against punishment as:

> *…all able family members (including wife with little child) are anticipated to contribute labor in SWC activities. When any one of the family members does not attend the program, the coordinators of the program punish us without considering our reasons for absenteeism. The kind of punishment can be either of cash and/or out casting from the social system.*

The discussion above underscores that though the expression of public participation in SLM practices are heard everywhere, from policy documentation to the pronouncement of the media, it remains rhetoric and more of theoretical dream than a practical reality.

The results suggest that the communities perceive the importance of SLM practices, acceptance and sustained use has not taken root. This is attributed to. Second, while community participation and integration of local knowledge have been underlined as a key dimension for successful SLM efforts, its implementation, in all most all agro ecological regions, remains rhetoric than a practical reality. This is perhaps due to a reluctance and resistance on the part of community and lack of commitment and well-established attitudes amongst government cadres, development agents and technical experts.

The study highlights that farmers will respond more favorably to incentives based voluntary approaches than they will to command and control systems to solve land degradation problems and to bring the desired outputs. We, therefore, argue that relying heavily on voluntary approaches and use of incentives to motivate farmers to adopt and use SLM practices is still the best alternatives.

7.2.7. Farmers' Attitude towards SLM practices and knowledge on their responsibilities: implication for Adoption

Attitude towards SLM practices and knowledge on land user's obligations were deliberately selected with the strong believe that these variables are key indicators that can be used to recognize and predict people's unseen feedback pertaining to SLM practices through integrated watershed management approach and would be imperative to implement demand driven interventions.

To obtain overall insight into these variables across all the three agro ecologies, farmers were asked to rate their response on thirteen selected set of statements (seven items for attitude & six items for responsibility) which were prepared based on empirical literature review and views attain from experts of the area. A continuum of five-point Likert scale, which ranges from strongly disagree to strongly agree, were used to indicate farmer's level of agreement or disagreement. A weight of 5, 4, 3, 2 and 1 was given to the respondent's response of strongly agree, agree, undecided, disagree and strongly disagree, respectively, which higher scores indicates farmer's favorable perceptions about the statement and lower scores suggested otherwise. The possible score which a respondent can obtain from each category range from twenty-five points (maximum) to five points (minimum) from which the average value was computed based on the number of responses in liker scale statements.

The indicator statements were further verified by conducting a reliability test. Cronbach's alpha value was used to determine the internal consistency of the scale developed to measure the extent to which questionnaire items were related to each other and the result ranged from 0.84 to 0.89, which lies within the recommended values of alpha (Tavakol and Dennick, 2011). As a rule of thumb, the higher the score, the more reliable the generated scale is. A low value of alpha was noted in the third category. This could be due to a greater number of questions which results in heterogeneous constructs.

The results demonstrate that the respondent's average agreement of the items that formed the farmers' attitude relating to SLM issues is relatively highest (mean = 4.49, SD= 1.47). Specifically, the items in this category includes farmers' attitude towards rehabilitation of degraded lands, abandonment of free grazing, communities’ role in managing area closures and soil fertility management issues, on which the majority of respondents agreed or strongly agreed on the stated statements.

Farmer’s attitude towards rehabilitation of degraded lands, use of fertilizers (organic and chemical) and proper maintenance of SWC structures on their plots are positive. The result also reflects farmers’ positive attitude to use chemical fertilizers and understand the side effects of using manure for cooking instead of for enriching soil fertility. Moreover, the majority of farmers showed their positive attitude on the prevention of soil erosion using various SWC structures and the need for undertaking maintenance work on the structures established on their plots. The result implies farmers’ positive attitude towards SLM practices in the watershed.

The second category (mean= 2.59, SD= 1.33) which consisted of six items was related to farmers’ moral obligation on SLM practices. Farmers’ were also whether they were aware of their obligation related to land use policy and proclamations which had been implemented in their region. The result reveals that, although the majorities of respondents believe that preventing soil erosion and associated land degradation as their own responsibility, knowledge on their obligations to properly manage the land under their holding and their understanding not to harm neighbors’ land as the result of misuse of their holding is inadequate. For instance, as can be seen from the Table 7.7, the majority of farmers were not concerned about off-site damages on neighbor’s adjacent plots as the result of their activities. The result indicates that despites many farmers believe that monitoring land degradation problems in their plot is their responsibility, the response on other items lies range from strongly disagrees to undecided scales. Table 7.9, below depicts the two categories, the 13 scale statements, the sub-scale means, standard deviations and internal reliabilities (Cronbach’s alpha value).

Table 7. 7: Indicators of farmers' Attitude towards SLM practices in the watershed (N=384)

Category	Survey items (statements)	Mean	Std. Deviation	Alpha
Attitude	I believe that SLM practices greatly improve productive capacity of lands	4.81	1.612	0.89
	I believe that SLM practices prevents land degradation	4.73	1.513	
	I believe that degraded lands should be closed from human and livestock interference for effective rehabilitation	4.82	1.613	
	I think Overgrazing should be stopped as it exacerbates land degradation problems	4.68	1.521	
	I think closed areas should be protected and managed by the local community	4.66	1.563	
	It is better to use cow dung and crop residue as a manure than as fuel for cooking	4.01	1.149	
	I believe that use of chemical fertilizers on my plots is important to improve land productivity	3.74	1.342	
Obligation	I believe that preventing my plot from soil erosion and associated land degradation is my responsibility	4.42	1.842	0.84
	I believe that it is my responsibility to stop free grazing as it exacerbates land degradation problems	2.67	1.31	
	It is my responsibility to undertake maintenance on soil and conservation structures installed on my plot	2.53	1.835	
	It is my responsibility to keep steep slope and marginal land out of production	2.32	1.823	
	I believe that my misuse of land would harm adjacent farm areas and owners	1.76	0.488	
	It is my responsibility to encourage my neighbors to adopt SLM practices	1.82	0.701	

Source: Field Survey, 2017

The findings from these studies demonstrated that the majority of farmer's existing knowledge regarding bundle of use rights, obligations and restrictions provided on the Rural Land Administration and Land Use Proclamation documents is still found to be rather low. Therefore, continuing efforts and concerted support should be made to create awareness among land users about overarching policies, laws and proclamations pertaining to resource use rights and obligations, as well as the mechanisms to enforce those rights and obligations.

The study identifies farmers are very familiar with the various land degradation problems but also key barriers to the translation of their knowledge into practice.

The study highlights a paradox that though the majority of farmers have an awareness of land degradation problems and better acknowledge the benefits of SLM practices, their sustainable land management investment was minimal. The finding further indicated knowledge on land degradation and positive attitude towards sustainable land management do not necessarily translate into actual practice.

This may be attributable to the existing top down approaches which made many decisions regarding to the selection and prioritization of technologies for SLM intervention without consulting & integrating local knowledge and enforce its implementation without regard for whether or not acceptable, which undoubtedly discourage farmers' participation, commitment and sustained application. The implication is that under this approach, SLM in the watershed might neither be effective nor sustainable. The result of this study is consistent with the study of Bewket (2003) who reported similar findings in Digil watershed, east Gojam.

7.2.8. Determinants of farmers' implementation of SLM technologies

As stated in the theoretical and conceptual framework, the implementation of SLM by farmers is inhibited by a range of bio-physical and socio-economic factors which are locally specific to the area of farming (Schmidt et al, 2018). Among variables considered in this study, total livestock units, use of hired labor, access to land management advice, credit access, participation in project and safety net program, Perception on the importance SLM practices and holding land use certificate were found either singly or in combination influence positively and significantly farmer's decision to implement SLM practices, while expectation of drought incidence influence significantly and negatively.

However, the remaining variables, such as age, level of education, family members, as well as physical factors, such as the slope of the farm, size, distance from residence, soil fertility status, and land fragmentation, did not significantly influence the implementation of SLM technologies and had only weak explanatory power in the model.Empirical results from logistic regression model are presented in Table 7.8.

Table 7. 8: Binary logit model result on the determinants of farmers' implementation of SLM technologies (N= 384)

Category	Variables	Coefficient	Standard Error	Wald statistics	Significance level	Odds Ratio
Personal and household attributes	Age of household head in years	-0.01	0.01	0.59	0.44	0.99
	Education Level of HHH	0.38	0.26	2.11	0.00**	1.47
	Number of economically active household members	0.16	0.13	1.65	0.2	1.18
Plot level characteristics	Plot's slope	-0.03	0.42	0.01	0.93	0.97
	Arable land Size owned by household in Ha	0.31	0.28	1.22	0.27	1.36
	Fertility status of plots	-0.27	0.3	0.84	0.36	0.76
	No. of parcels owned by household	-0.03	0.05	0.33	0.56	0.97
	Plot distance from home	-0.01	0.01	0.34	0.56	0.99
Socioeconomic Assets	Total livestock units owned by household (TLU)	0.21	0.08	6.22	0.01*	1.23
	Off-farm activities	0.44	0.33	1.81	0.04*	1.55
	Use of Hire labor	0.69	0.26	6.88	0.01*	1.99
Institutional support and Local cooperation	Access to land management advice	0.6	0.27	4.74	0.03*	1.82
	Credit access	0.93	0.55	2.82	0.002*	2.52
	Being within Project site	1.34	0.33	16.37	0.00*	3.8
	Participation in safety net program	0.34	0.37	0.84	0.01*	1.41
	Incentives from the government	1.24	0.26	22.94	0.00**	3.45
	Cooperation of farms with each other (labor sharing)	0.69	0.26	6.89	0.00**	2.89
Perception of benefits, costs and Risk	Perception on the Importance SLM practices	0.62	0.31	4.03	0.04*	1.85
	Holding land use certificates	1.06	0.6	3.06	0.02*	2.87
	Expectation of drought incidence	-1.61	0.29	30.25	0.00**	5.02

*Significant at 5% level; Hosmer and Lemeshow chi-square= 10.78; - 2 Log likelihood = 393.59; model chi square =135.37; Cox and Snell R^2 =0.3; Nagelkerke R^2 = 0.4; Percentage of correct predictions = 75.5 %.

7.2.8.1. Personal and household attributes

With the exception of age, all the demographic variables incorporated in the model have shown positive effect on farmer's decision to implement various SLM technologies. However, except education levels of household heads, all other variables were not statistically significant. Level literacy of the household head is mostly presumed to be an important variable to have positive impact on the implementation decisions of SLM practices. The binary logit analysis results (Table 7.1) suggest that educational status of household head positively and significantly (<0.01) influences the implementation of SLM practices. This could be associated to the fact that education level is an important factor in building individual's capability for learning, for interpreting information, and for comprehends benefits of SLM measures. Furthermore, the education of one individual often increases the learning of others in the family members and the community at large. In this study, it was found that household heads who at least read and write were more likely to apply one or more SLM technologies. This suggests that households which are headed by relatively more educated heads are in a better position in terms of implementing SLM practices. Similar results were reported by Amsalu & De Graaff (2007).

The availability of family labor in the household is one of the important demographic variables affecting SLM practice. Most of the SLM practices such as construction and maintenance of water erosion control measures and transportation and spreading of manures are very labor demanding activities where labor constraints influences farmers' investment capacity.

7.2.8.2. Plot level characteristics

Land is one of the main physical assets of farmers in the study watershed. Plot level characteristics influence farmers' decision in which plots to invest (Admasu et al., 2012). Except the plot size variable, that had a Positive effect on famer's decision to implement SLM, all other plot level explanatory variables included in logistic model had the negative relationship. While plot size has positive relations, the analysis shows that other farm characteristics such as plot slope, fertility status, number of parcels and distance of parcels from residence showed negative effect on the implementation of SLM practices.

As indicated in chapter three, the size of land holding of sampled farmers in the watershed varied from lower than 0.25 ha to more than 1.25 ha with the mean holding of 0.75 ha per household. Albeit statistically not significant, it was found that farmers' decision to implement SLM practice increased as the size of the landholdings increases. This means farmers with higher farm size have better tendency to use, for instance, introduced SWC measures sustainably than those who have less farm size.

7.2.8.3. Socioeconomic Assets

All socio-economic explanatory variables included in logistic model had significant positive influence on the implementation of SLM practices. This shows that economic factors were the main reason for actual implementation of SLM technologies suggesting to prioritize an SLM option that is economically attractive.

As noted by Shiferaw and Holden (1998), the number of livestock owned by the farmers is a proxy indicator of his or her wealth status. Our findings disclose that farmers with large number of livestock have shown better investment in their plots. This could be explained by the fact that livestock are assets that can be easily converted into cash to purchase external inputs such as inorganic fertilizers. Manure obtained from the livestock can also be an important source of organic fertilizer for farm lands. Livestock also provide draught power which is important in SWC practices such as construction of drainage ditches and *fanyajuu* terraces. Moreover, farmers with more livestock were more likely to apply manure. This is in line with the finds of Nigussie et al. (2017) and Teklewold et al. (2013). However, it contradicts with the findings of Amsalu (2006) who indicated significant negative influence of farmers' livestock holding size specifically on the implementation of stone terraces. But in this line, it is unfortunate to note the authors' concern that although there is positive complementarities between livestock and SLM practices, increasing the number of livestock might cause environmental burden.

This study also found positive and significant link between use of hire labor and farmers' decision to implement SLM practices. The study reveals that those households who had the ability to pay for hired laborers were more likely to invest on SLM practices. This implies that labor constraint is one of the major challenges which discourage farmers to apply various SLM technologies in the watershed.

Off-farm activity is another socio-economic variable which was found having influence on farmers' decision on the SLM activities. As the out put of the logit model indicate, the odds of SLM implementation increase close to double among households whose family members were engaged in off-farm activities as comared to non participant farmers. During the post-harvest season, temporary labour migration into urban areas is common among few poor but able boded farmers to generate income through hire out their own labor. Although local off-farm income opportunities in the study area are limited in availability and income-generating potential, the survey results reveal that those households who participated in off-farm activities were more likely to implement SLM practices (probably as they have a extra source of earnings) as weigh against those who don't. In fact, it is essential to point out here that income generated from off-farm activates are mainly used to pay annual land use tax and cover expense of other essential household needs and hence, it is rarely channeled to SLM investments.

This finding contradicts to the reports of Demeke (2003), Amsalu (2006), and Tenge et al (2004), which state that taking part in off-farm activities negatively influences the implementation of SLM measures due to competition for labor. This result implies that the research reports on the relationship between off-farm activities and SLM implementation decisions are still inconsistent.

7.2.8.4. **Institutional support and Local cooperation**

The implementation of SLM technologies was also positively and significantly affected by the provision of support services. Participation in government initiated SLM program (being within project site), government support through well designed and participatory extension service, subsidies (e.g. productive safety nets programme), and credit access increased the probability of SLM implementation.

Farmers participated in the SLM program project site show better SLM investment efforts as compared to others. The odds of implementation were calculated to be four times higher in farmers whose family members are participating in the project. This implies that government-initiated programs significantly increased the probability of farmers' investment in the SLM technologies. This could be attributed to farmers participating in SLM program are more cognizant of the problems of land degradation and develop better experience on the benefits of SLM practices. In addition, the government projects have been encouraging, technically and financially to the farmers to implement SLM technologies. Similarly, investments in PSNP have a positive and significant effect impact on the implementation of SLM practices. Farmers who participated in productive safety-net programmes were found to have increased odds of applying SLM practices by a factor of 1.4 higher when compared to non participant farmers and the result is statistically significant ($p<0.05$).

Likewise, farmers' cooperation in SLM related local labor sharing and mutual labor assistance, (locally known as '*wonfel*' & '*Debo*') showed significant influence on the implementation of labor intensive SLM practices such as terracing. This approach is a long tradition cooperative commonly practiced among farmers in the watershed and it is vital not only to solve labour constraints but also to discuss common problems, explore solutions, share experiences and improve farmer cohesion. This calls the need for strengthening these vital social capitals which influence farmers to have a greater tendency to participate in SLM practices.

Farmers who have better access to information/advice about the importance of SLM practices have been found to be more likely to implement SLM practices. More specifically, the odds of SLM implementation were found to be 1.82 times greater for farmers with access to SLM advice, if the influence of other independent variables is held constant, suggesting the need for promoting information dissemination and creating awareness pertaining to the importance of SLM practices through disaggregated approaches based on farmer's heterogeneity in terms of awareness level and farm-specific characteristics. This calls for targeting extension outreach so as to propagate the required information and to raise awareness on the benefits of SLM technologies.

In general, institutional support such as the use of technical advice or extension services is found to play vital role in promoting SLM investments. Comparable results were reported by Adimassu et al. (2014) in the central Rift valley of Ethiopia and Nyanga et al. (2016) from West Usambara Highlands of Tanzania. This suggests for promoting effective farmer-institutional support linkages and strengthening indigenous labor sharing approaches among farmers.

Incentives provided from the government were found significantly increased the likelihood of farmers' investment in the SLM technologies. This implies that since SLM benefits ensue overtime, incentive of any kind is still vital to enhance the chance of its uptake. The result is consistent with the studies of Boardman et al. (2003) who reported that farmers in the developing are very much influenced by economic incentives.

This study also shows that access to credit facility was positively and significantly related with SLM practices. However, the majority of the farm households do not take credit for meaningful land management investment due to lack of access to these institutions (though there is Amhara credit and saving institution in the district town) or fear of high interest rate. Moreover, most of the farmers that are commonly taking credit are the poor ones, with less land holding and other resources. For this group of household, the priority is in feeding their families instead of planning for SLM practices. Nevertheless, some farmers borrow mainly from informal sources of social networks such as neighbors, friends, or families to purchase inputs such as commercial fertilizers. This implies that credit constraints negatively influence investment in SLM (e.g. application of inorganic fertilizers) and calls for improving credit delivery systems.

7.2.8.5. **Farmers' perception of advantages and risks**

This includes perceptions on the benefits of SLM practices, expectations of rainfall variability and drought incidence, and certificate holding. Variables related to farmers' perceptions of advantages and risks have been identified as significant catalyst for decision to implement SLM practices. The parameter estimates for farmers' who evaluated SLM practices as importance was positive and statistically significant. For instance, if farmers acknowledge the importance of use of chemical fertilizer, its application will be enhanced. Put in other words, farmers expecting higher returns from an SLM activity are more likely to participate in its implementation.

This implies that SLM intervention measures that boost the productivity of the land encourage farmers' decision to implement. This result is concomitant with the findings of Amsalu and de Graaff (2007) and Nigussie et al., (2017) in Central and north-western highlands of Ethiopia respectively.

Conversely, perception about climate risk, uncertainty and high input prices discourage uptake of SLM practices. For example, if farmers frequently perceive risk of crop failure due to lack or shortage of rainfall, they could not invest on inorganic fertilizer and crop rotation practices. Moreover, farmers who perceived drought as a cause of death for tree seedling, he/she will not plant trees. In this vein, many farmers in the study sites explained that drought incidence was one of the main reasons that discourage their decision to implement SLM practices.

From the model output, it was found that farmers' perception about the negative impact of drought incidence on their cropland discourage the decision of SLM investments in the watershed. It was for this variable the highest odds ratio derived in the model. Holding all other factors constant, perception of climate risk has a significant inverse relationship with the implementation of SLM decisions. The model output unveiled that the odds of SLM implementation decrease five times for those farmers who fear the impacts of drought incidence as compared to the corresponding farmers who do not fear probability of the incidence. This evidence highlights the importance of better rainfall forecasts information for SLM initiatives.

The finding also implies farmers who hold land certificates were more likely to invest on SLM practices. This implies lifelong tenure security, particularly in such areas where land redistribution experiences were common, is important to enhance farmers' long term SLM planning and investment visions. It also indicates clear land use rights for farmers, not only reinforce sustainable local investment but also make sure equity of such rights among women and men.

Nevertheless, this seems not always true as more than 90 percent of the sample farmers received land use right certificates but the majority of them are not eager to implement SLM practices on their plots. This finding is consistent with the studies of Teklewold et al. (2013); Teshome et al., (2015) and Nigussie et al., (2017).

The overall empirical results from the binary logistic regressions indicate that farmers in the watershed have been influenced by multitude of factors (though skewed more towards to institutional and attitudinal factors) when they implement plot-level land management decisions. Farmers with better resources endowment (such as livestock holding, ability to pay for daily labor etc), better access to information, better extension services, participation in land management related government intervention program , collaboration among farmers encourage the uptake of SLM practices on their plots. Hence, to enhance prospects of success, factors that hinder farmer's actual SLM implementation need to be addressed. This implies that the ongoing "one size fits all" approach in SLM planning and implementation is not yet effective. Different farmers have different needs, interests and challenges facing them. Hence, SLM interventions should fit to local circumstances, reflect on the diverse needs of the farmers, solve the challenges they face, and consider the balance between short-term gains and long-term goals. Though individual level recommendation is unrealistic, it is possible to categorize farmers based on agro-ecologies and socioeconomic variability for recommendation of SLM options (Scherr et al., 2012; Cordingley et al., 2015).

To triangulate model results, focus group discussions were held and farmers were asked to state challenges they have been faced to effectively implement SLM practices. The result revealed that labor shortage, lack of working capital (to purchase farm inputs), recurrent drought which discourage farmer's sustained use of recommended SLM practices, small and fragmented land holding, shortage of manure due to decreasing livestock size and lack of commitment (in their words 'laziness of some farmers') were among the wider range of reasons distinguish and justified. Similarly, some emphasized the common limitations of the recommended technologies such as high maintenance requirement (e.g. SWC structures), incompatibility to indigenous farming systems, failure to recognize the role of livestock in the farming system by the government. Contrary to this, key informants from the local government and development agents blame farmer's lack of commitment and working spirit for this situation.

The final suggestions of these group discussions participants were provision of incentives for these farmers who successfully implement SLM practices and penalizing of those who violets the community bye-laws and intentionally degrades particularly communal resources. Moreover, local labor sharing traditions should be strengthened to promote farmers' decisions to implement various SLM technologies.

7.2.9. The success stories of SLM practices: Evidence from SLM program target sites

The SLM program has been implemented in some selected micro watersheds of the study area since 2014 and there are some vissible success stories from this intervention. Some of the ongoing activities undertaken by SLMP include: SWC and management; Livestock management; Crop management; Reforestation and rehabilitation of degraded hillsides; Pasture/forage management; Rural biomass and energy saving; Community feeder road construction; Establishment and development of community-level institutions and Community skills development. Respondents were asked to evaluate the overall current status of their locality as compared to before the program intervention. From the general feeling of the community, it is clear that this micro watershed part has been put in a much more favorable position than it has ever held in the past.

As noted from field observation of the target sub watersheds sites and official reports, because of the intervention of the program, free grazing has been reduced, hillsides and degraded lands have been treated by area closures supported with hillside terraces and other moisture harvesting structures, and the erosion mitigation measures has been implemented following the watershed logic. However, SLM activities of the watershed skewed more towards the investment on physical SWC structures in comparison to other components. Moreover, actual implementation levels and success stories vary across agro ecologies and among sub watersheds.

According to the survey respondents and the FGDs in the sub watershed, these days the magnitude of land degradation has been reduced by the watershed treatment. As it can be observed from Fig. 7.11 the intervention has brought some observable positive changes in the bio-physical condition of the sub-watershed. The personal observation of the researcher has also testified this fact.

> *Before the SLM program, land degradation was so severe that we were almost stopping farming, said elder Mohamed Assefa. But the coming of the program brought encouraging measures to address land degradation problems in this area which was frequently struck by drought and associated famine. Currently, the program support on tree plantations in and around homesteads. The program provided us tee saplings free of cost. You can see how the area is transformed pointing out the grass covered hillsides.*

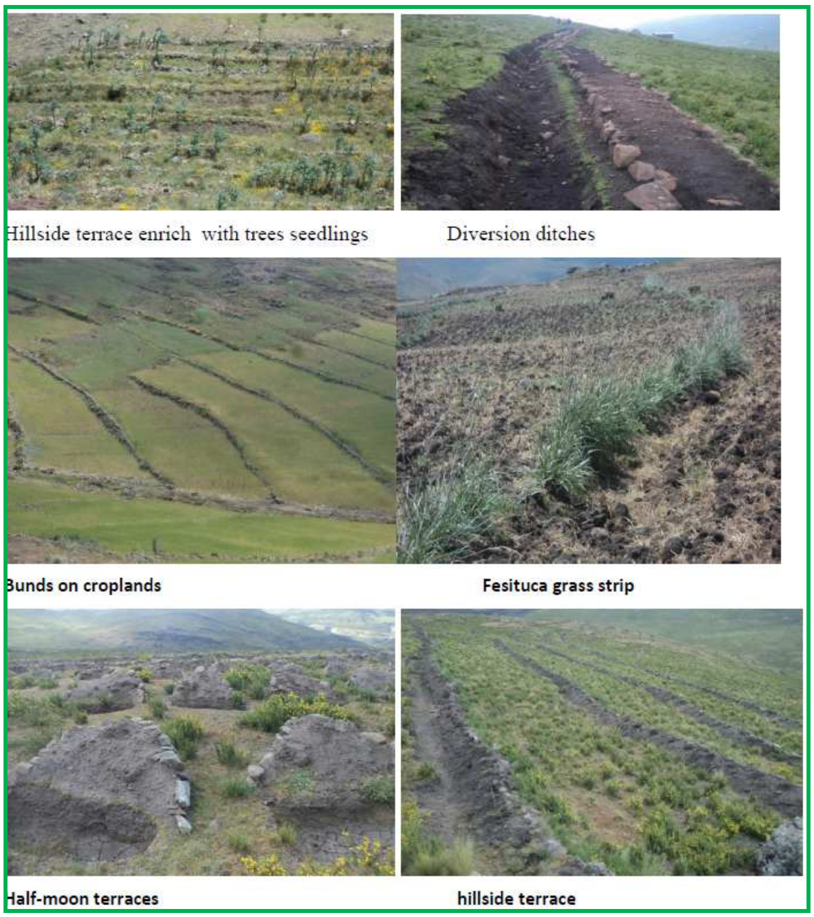


Figure 7. 10: Various SWC structure implemented at the Watershed (Photo: author**, 2016)**

7.3. Farmers' Perceptions on the outcomes of SLM practices in the watershed

7.3.1. Perceived outcomes on biophysical environments

It is indeed challenging to estimate precisely, mainly in a quantitative way, the impact of SLM program interventions on the biophysical and socioeconomic outcomes, particularly if there is no counterfactual information available for comparison purposes. Although impact assessment would require more rigorous and careful techniques such as Propensity Score Matching and/ or difference-in-difference approach, the authors unlikely used more sophisticated statistical or econometric tools for this study due to paucity of the required data. Hence, most of the analysis of SLM program intervention outcomes on selected biophysical and socio-economic parameters rely on qualitative data stemming from farmers' perception and own observations in the study watershed. As it is based on the accumulation of continued observations, the authors believed that farmers' perception provides accurate information on the biophysical and socio-economic outcomes of SLM intervention program in their localities.

On the basis of the proceeding premises, farmers were asked to rate their perceived outcomes of SLM program interventions on selected environmental parameters relative to before interventions (five years ago). The results highlight that there were divergent views of framers residing in the SLM program intervention sites and non intervention sites. Almost half of (49.7%) the respondents either agreed or strongly agreed on the improvement of vegetation cover due to SLM program interventions in the watershed (Table 7.10). Almost equal number of respondents, however, had a contrary perception of it. The vegetation improvement recorded in the sub watershed could be ascribed to the implementation of enclosure strategies and bund stabilization practices through biological measures on farmlands (Fig.7.12)

Figure 7. 11: Bunds stabilized with vegetation (Keyafer sub watershed **(photo: authors, 2017)**

Similarly, close to half of (47.7%) the farmers have either strongly agreed or agreed on the statement stating "increasing of fodder availability for livestock". This could be attributed to the improvements in vegetation cover and the effects of the ongoing implementation of physical SWC measures in both cropland and non-cultivated lands. Contrary to this, the majority of farmers have either strongly disagreed or disagreed to the statement that indicates transformation of unproductive lands in to productive ones (86%); increase in biodiversity (61.7%); fuel wood availability (57.8%,); progress in availability of waters for humans and animals drinking (68.3 %) and improvement in microclimate of the watershed (75.8%) .

It seems paradox that on one hand there were perceptions of the general increase of vegetation cover of the watershed on the other hand there were experience on the lack of improvement trend in the status biodiversity, local climate, fuel wood access, and water availability over time. The inconsistency might be the recent increase in the vegetation cover of the watershed in response to the ongoing watershed management activities may take time to restore biodiversity, improve local climate, supply fuel wood and improve water resources.

Nevertheless, some farmer and expert key informants (coordinator of natural resource management and protection unit, leaders of development teams, Development agents, *Kebele* administrators) of the district, stated that it is not only the density of vegetation cover that has increased, but also some wild animals have restored to the protected landscapes and increase their numbers to the level that residents complain of crop damage and livestock attack by these animals. For instance, a good number of wild animals such hyena, Tiger, Monkey, Apes, and Semen Fox (Canissimensis) currently live in the escarpment upper and top portion of the watershed. This is a potential for ecotourism development in the area. Likewise, the recovery of '*Gaussa'* grasses generate many benefits to the local communities such as forage for livestock and good source of income through sale when livestock feed is scarce elsewhere (Fig. 7.13). The majority of them also stated that SLM program has changed most of the formerly barren land into enclosures and enhanced natural regeneration of vegetation covers in the watersheds.

Figure 7. 12: **Guassa grass on the way to the local market (left) and enclosures (right)** (photo: author, 2016)

yet, the majority of key informants' farmers from non project intervention sub watersheds do not agree with the preceding explanations and stated that the watershed management program has had bring insignificant contribution to the progress in vegetation cover, fuel wood availability and reduction in flood occurrence in their localities. They stated that had it been vegetation covers improved, they would have not been suffering from lack of fuel wood. They also argued that since there is no maintenance made on SWC structures constructed through annual free labor campaign, runoff has been increasing from both croplands and communal lands because of the partial or complete ruin of the SWC structures due to various reasons.

Table 7. 9: Farmers' Perceptions on biophysical Environments (% of the total)

Parameters	SD	D	NS	A	SA
Increased in vegetation cover of communal areas in the watershed	1.8	42.2	6.3	46.1	3.6
Unproductive have been turned in to productive lands	32.3	53.9	7.8	2.3	3.6
Increase in biodiversity of the watershed	4.4	57.3	7.3	29.4	1.6
Availability of waters for humans and animals drinking improves	33.1	35.2	6.5	24.7	0.5
Availability of wood and woody biomass (for cooking, heating, and lighting) increases	17.7	40.1	1.6	37.2	3.4
Increase in fodder availability for livestock	31.3	17.9	3.1	44.3	3.4
Microclimate of the watershed is improving	30.5	45.1	5.5	11.7	7.3

SDA= Strongly Disagree, D= Disagree, NS= Not Sure, A= Agree, SA= Strongly Agree
Source: Field survey, 2017

7.3.2. Perceived outcomes on local livelihoods

Local communities were asked to state their perceptions on the outcomes of SLM practices on some livelihoods components vis-à-vis land productivity, livestock ownership and productivity, access to training and capacity building, household assets, annual income, extent of participation in community work and community cooperation, access to infrastructures, and so on. The results asserted that the largest proportion of respondents show their disagreement on the overall improvement of these components (Table 7.10). For example, from the survey analysis, it was observed that more than 80 % of the farmers showed their disagreement on improvements in crop production, production assets, household saving habits, annual income, food insecurity status, saving habits and access to safe drinking water (Table 7.10). An attempt was made to further investigate the number of months the household faces food shortages. Although the response varies from none to nine months, chronic food shortage was highly prevalent in *Wurch* agro-ecology of the watershed. The reasons for the shortage of food in this part of the watershed were lack or erratic nature of *Belg* rain which results in total failure of crops and limited coping mechanisms at their disposal. This was aggravated by lack of access or high price to purchase food crops from the local markets. Hence, many of the households rely on food aid. The findings are supported by similar studies conducted elsewhere in Ethiopia which reports food insecurity is more likely prevalent among households residing in the higher than lower agro-ecological zones (Yirgu, 2013; Motbainor et al. 2016).

Nevertheless, it is also exciting to see a relatively higher proportion of the farmers perceive improvements in some physical assets such access to health centers, housing standard, access to schools, access to mill (machinery for grinding grain into flour) and road networks after the intervention of SLM program in the watershed. It must also be understood that most of the positive responses for the evaluation was given from *Dega* and *Wurch* zones where SLM program operates.

Table 7. 10: Distribution of farmers' perception on key indicators of rural livelihoods (% of the total)

S/N	**Parameters**	SD	D	NS	A	SA
1	Community training and capacity building programs intensify	40.4	45	7.8	3.9	2.6
2	Level of awareness o resources degradation increased	22	44	17.2	13	3.7
3	Knowledge and skills of SLM activities have improved significantly	15.8	32.2	14.5	22.9	14.6
4	Extent of participation in community-based watershed management practices improved	37.2	2.1	21.4	38	1.3
5	Social relationship (e.g. informal work exchange, *Iddir (Qire*) and network strengthen	39.8	34	21.9	3.1	0.8
6	Adherence to rules and regulations including community by-laws	38.5	54	1.3	3.6	2.3
7	Level of women's participation in the community improved	44	41	6.5	3.9	4.2
8	Annual crop production per unit area increases	30.5	56	3.9	8.1	1.6
9	Livestock ownership and productivity increases	25.8	43	24.5	2.3	4.4
10	My means of production assets improves	32.8	55	6.3	3.6	2.6
11	Possession of mobile phone & radio among community increased	39.8	21	26	11	2.9
12	Access to road networks improved	26	31	1	31.3	10.9
13	Access to education (e.g. Schools) improved	4.7	29.4	1	35.4	29
14	Access to veterinary service improves	34.1	48	6	5.7	5.7
15	Access to Health centers & facilities improved	6.3	21	3.1	36.2	33.1
16	Housing quality of the community improves	5.7	33	14.3	35.4	11.7
17	Access to Pipe water improves	49.8	34	5.2	3.9	7.3
18	Access to mills improves	4.2	20	21.4	39.1	15.1
19	Access to financial services (saving and credit facilities) improves	41.9	48	5.9	2.6	1.4
20	Household saving habits improves	53.9	35	4.2	3.4	3.4
21	Total annual income cover household expenditure	35.7	47	10.9	3.6	2.6
22	Food security status of the community improves	46.4	34.2	2.6	7.4	9.4

SDA= Strongly Disagree, D= Disagree, NS= Not Sure, A= Agree, SA= Strongly Agree
Source: Household survey, 2017

7.3.3. Overall Performance of SLM practices from livelihood assets perspectives

The main performance indicators criteria considered for the overall appraisal of SLM practices on local livelihood capital assets (Natural, Human, Financial, Physical and Social)was mainly based on the perceptions of local residents as indicated in Table 7.9 & Table7.10 above. The asset pentagonal radar was constructed to display schematically the results of perceptions of rural households. Radar diagram was constructed after weighting the perceptions of the respondents on selected indicator criteria through likert scale approach and considering the mean values for each livelihood capital assets components. The idea is that the point in the midde of the pentagon, where the lines meet, represents no any outcomes to livelihood capital assets while the outer perimeter represents maximum values.

From the comparison analysis performed, it was evident that outcomes to natural and physical assets were relatively better and almost similar as their position is far away from the centre of the pentagonal radar. The financial capital, which is relatively closer to the centre, was the least outcome asset followed by Social capital outcomes. These findings suggest that financial assets such as saving habits, access to financial institutional services, alternative and diverse source of household income are still minimum suggesting low capabilities to cope with and recover from natural or man-made stresses and shocks. Similarly, social assets such as community solidarity, community-based organizations, active social participations, and gender empowerment are still challenging.

The overall performance on the human capital such as knowledge and skill transfer through community training and capacity building was not significant. Since human capital is the means of achieving sustainable livelihood outcomes, the government should device effective and sustainable mechanisms to improve human capitals among the community.

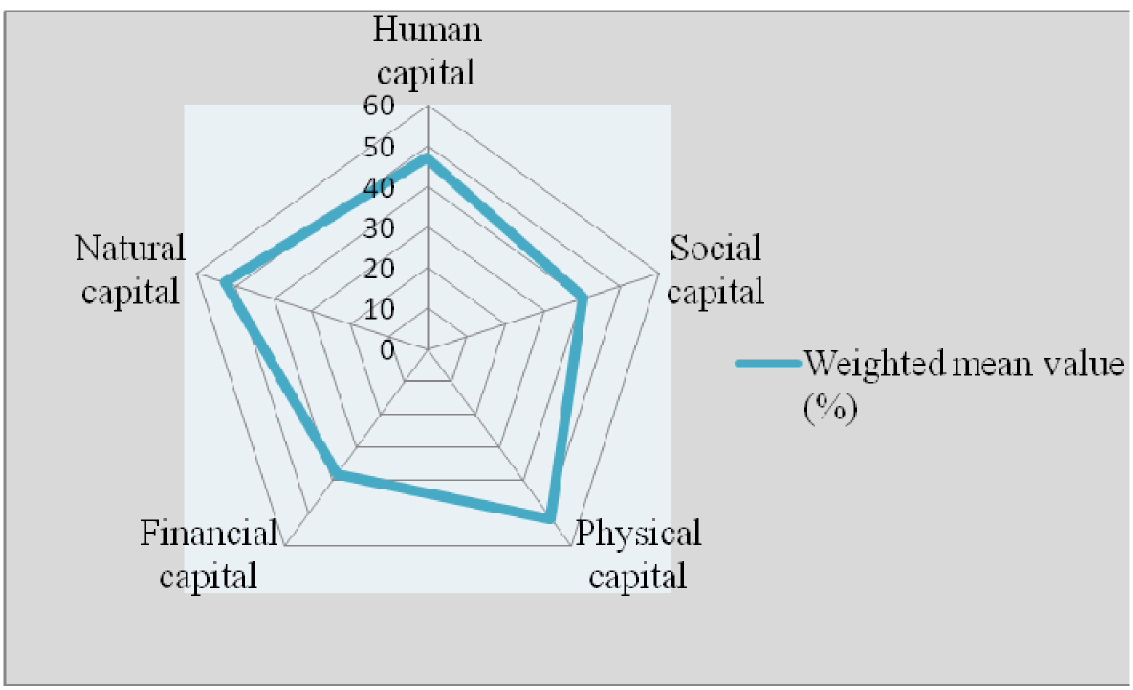


Figure 7. 13: Livelihood asset pentagon in the watershed

7. 3.4. Success stories from SLM program participating f*armers*

The following story of some 'progressive' farmers clearly shows the promising impact of SLM practices and its ultimate benefit in changing lives of rural farmers.

Case: I

Ato Yaregal is a small-scale conversant farmer from the Sengolla Kebele. He is 35 years old, and owns 1.25ha of land, two oxen, two cows, and 16 shoats. He has two children in the household. Yaregal can read and write and has good links with development agents assigned the Kebele and he always listens to the advantage of land management programs broadcasted by radio and accepts the advices given by the development agents. He has adopted a variety of SWC measures to protect his farmland from erosion hazards and enhance its fertility. He, not only maintained soil and water conservation structures constructed on his farmland, but also implement grass strips, which is very important, as he said, in reducing soil erosion problems, improve soil fertility status and useful as fodder for livestock. When asked about the overall impact of his efforts, Yaregal replied that, although the activities are tiresome and labor intensive, the outcomes are very attractive. He also spread manures on his cultivated lands to maintain soil fertility. He is very proud of his farming activity and he confidently explained that he never faced food shortage of life time even during the drought years.

Figure 7. 14: Heap of manure collected from animal dung and house rubbish to spread on his crop lands (photo: author, 2017); Source: Field Survey, 2017

Case: II

Ato Tilahun, 42, is one of the model farmers in Cherer sub watershed of Sengolla Kebele. He is known to be one of the hard worker successful farmers in the Kebele. He learned the benefits of SLM technologies from radio and the DAs of the kebele as well. For the last 5 years, he has been constructing and maintaining SWC measures on his farm land and using chemical fertilizers. He planted strips of phalaris grasses to stabilize the structures. When asked about the sources of the seed, he said "Over one season I brought seeds of this grass from other kebeles when I heard its benefit from somebody else," said Ato Tilahun, pointing to the need to establish a network between different communities to share their experiences with a view to learning from each other. He added, I learned the grass now did better to protect soil from erosion and stabilize the stone terraces on my farm. As he puts it: "Before, the application of such measures this land was regarded as unproductive. But now you can see for yourself the grass is improving the soil in my farm and used as animal feed". He added that "His yields have been so good that he not only able to satisfy his food requirements but also he has had food left over for his neighbors. When asked about the reaction of his neighbors and friends, he said, as a farmer I am proud as many farmers have admired my effort. He has taught other farmers and some of them are promising to use the practice and reaping its benefits". He uses a micro-irrigation scheme to grow cabbages, onion, carrots, etc in the homestead for sale and consistently applied manure to these vegetable gardens.

Figure 7. 15*: Phalaris grasses (left), and Vegetable (right) *(photo: author, 2017); Source: Field Survey, 2017*

Case: III

Kedija is 37-year-old widowed exemplary women living with her two sons. Her husband died two years ago. Like many other people in her village, Kedija used to feel that there were limited opportunities to earn income in her village. After some encouragement from the kebele, she received training in how to farm poultry effectively to get the best results and she decided to start poultry farming activities thereby to support her family from the income. Apart from farming, which has been her primary activity, she borrowed money from Amhara credit and saving institution and started poultry farming. Her sons support her in feeding chickens and cleaning the areas of poultry and collecting eggs. Currently, her income is rising to the extent that she has built a new house and she is now able to support herself and her family, whilst still saving some money. Visiting her home, it was found that, at present she has more than 55 chickens. In last three months, she has sold at least 30 hens and cocks and more than one thousand eggs. When asked her long-term plan, she replied, proudly with a full smile and a frontward gesture, “I have a dream to diversify my income and support my two sons’ education to the University levels who are currently attending in the elementary school. As she added, she has been motivated by visits from Woreda experts and cabinets. She is proud of by her effort and she can confidently show visitors what she has done in her village.

Figure 7. 16: Poultry farming in Wukir sub watershed (photo: author, 2017); Source: Field Survey, 2017

The preceding cases highlighted that rural families in the study watershed have livelihood diversification alternatives such as highland fruit, small poultry farms, livestock and shoat fattening in order to enhance livelihood security and standards of living. The result breaks the old aged local community’s premise and deeply entrenched attitudes of “*crop cultivation is by no means the only livelihood opportunity*” in the area. The results also signify that gender issues do not affect income earning opportunities and diversification options in the watershed. Based on the foregoing notion, expansion of opportunities and minimizing constraints for livelihood diversification are desirable component in SLM activities.

Summary

The findings from the of the watershed revealed that though many SLM technologies already in place to control land degradation problems at the watershed and farm level, many of these technologies were not effectively and sustainably used in the watershed. The study result revealed that past attempt aimed at reduce land degradation in the study area have not achieved intended objectives of wide application of SLM practices in the watershed. The success of most of the land management practices implemented on the watershed were limited due to poor in technical specifications and design, weak follow up and monitoring, lack of consideration for the requirements, interests, restraints and livelihood realities faced by farming households. Among others, top-down planning and implementation schemes, ignoring overarching national level policy and implementation guidelines, poor enabling environment for local-level community participation, inadequate capacity of institutions, and insufficient knowledge and technology diffusion hamper the success of interventions.

In general, the findings of this study indicated that farmers realized the dwindling natural resource base drastically. Most of them also acknowledge the need for SLM practices; successful sustainable land management efforts, its implementation, in all most all agro ecological regions, remains rhetoric than a practical reality. This is perhaps due to lack of commitment amongst government cadres, development agents, technical experts and the farmers themselves.

The findings of this study also realized the potential of SLM program projects as a vehicle to promote sustainable land management provided that the capacity of institutions at local level is built and the local government is committed to supporting them.

CHAPTER EIGHT

8. Challenges and prospects of SLM practices in Gedalas Watershed

8.1 Introduction

Sustainable poverty alleviation, food self sufficiency, environmental sustainability, facing climate change adaptation and other economic possibilities are impossible without ensuring SLM practices. In the current scenario, though there are considerable efforts to fight land degradation and promote SLM practice in Gedalas watershed, the successful adoption is not observed as desired. This chapter provides a snapshot of key constraints to effectively implement sustainable land/watershed managements and discusses prospects ahead for its promotion in Gedalas Watershed.

8.2 Promotion and Sustainability Challenges of SLM in Gedalas watershed

8.1.1 Recurring Drought and long term dry spells

Recurrent droughts and high degree of rainfall variability (both in space and time) has long been a feature in the study watershed and are exacerbating processes of environmental degradation. There is a strong link between droughts and SLM. Drought can exacerbate the impacts of land degradation and reduce the viability of some options for avoiding, reducing and reversing land degradation. The impact of almost all direct drivers of land degradation will be worsened by Drought. These include, among others, accelerated soil erosion on degraded lands as a result of more extreme weather events, increased risk of forest fires and changes in the distribution of invasive species. Drought, not only exert on biological SWC measures (ex. Trees), but also made them to be susceptible to attack by insect pests and pathogens (Bentz *et al.,* 2010; Kotiaho& Halme, 2018). Moreover, the perceived high risks of crop failure due to unpredictable rains restrict farmers from use fertilizers as land management strategies. Drought results in reductions in agricultural yields which can in turn undermine households' abilities to invest in land management inputs.

Since local communities in the study area excessively depends on rain fed agriculture, missing one season's harvest or having a considerably low harvest due to a shortage of rain event can leave local farmers with nothing to fall back on (pessonal communications with farmers, 2017).

This has created overarching challenges for the poor rural local communities due to their limited adaptive capacity and high reliance on fragile land resources. In this regard, the experience of the farmers at *Wurch* and High *Dega* agro ecological zones of the watershed has been quite exemplary. One of the elderly key informants from *Gaya Kebele* narrated his experience related to the rainfall variability *in case of Belg season* as:

> *We cannot be sure that rain would occur adequately in the course of the whole growing period. In some years rain started normally. Then we sow barley. It normally germinated and reached*

certain stage of growth. The disaster came afterwards. The rain stopped, and never returned, despite our day and night appeal to God. Finally, crop failed and left the farms empty because of moisture stress and we harvest nothing.

Strengthening impacts of drought, another key informant, a resident of *Wurch* agro-ecology, explained the situation this way:

> *We are now more confused and living in fear, as we are not certain whether to continue farming or not, since there is less rain and frequent droughts. Farming is the primary sources of our income, so we are worried as unfavorable rainfall threatens our food security status and limits our livelihood options. I remember two years back; it was horrifying that my land that I depend to nourish my family was impacted by drought.*

These farmers highlighted that the extent of the vulnerability status of the watershed on the negative impact of rainfall shortages and drought incidences. The author was in the field during the 2016/7 *Belg* season and got the chance to witnessed failure of Barley crop at the Belg growing sites of the watershed. During drought periods crop failures and food scarcity are not uncommon, pasture and water become much harder to find, resulting in high livestock death. It was in line with this reality that Little et al., (2006) state the incidences of drought in Wollo, where the watershed is part of it, as follows:

> *…it is common to hear heart-wrenching stories of death and massive asset losses due to droughts in the South Wollo area of northeastern Ethiopia. People's ability to make a living in this impoverished and risky part of the world is clearly challenging, even when compared to other low-income areas of rural Africa.*

Another key informant farmer aged 46 living in *Weyna Dega agro-ecology*, affirmed the challenges of drought incident to invest on inorganic fertilizers as SLM technology options as:

> *Last year (2017), I had borrowed some money from my friend for purchasing fertilizer. I expected that after getting good production returns, I would pay back the money to my friend. But due to drought I lost my investment and I failed to pay back and remained indebted.*

This vibrantly implies that the drought incident not only ruined farmer's asset but also discourage farmer's investment planning and implementation of SLM technologies in the watershed.

8.1.2. Institutional capacity for policy implementation and enforcement

Instititions involve the realization of land related policy prescriptions, proclimations and programs following implementation guidlines. However, institutional capacity to implement is one of the chief constraints witnessed in the watershed. Effective implementation of SLM requires strong institutions with clear understanding of what it involves. As per the current organizational structure of Ethiopia, local government authorities at district, watershed and village levels are accountable for the protection and sustainable management of natural resources. The district has responsibilities to combat land degradation problems and rehabilitate degraded lands. However, this study identified that most local government departments have severe resources limitations in terms of staff complements, skills and funds in promoting SLM practices.

Another most common barrier observed in the watershed is the limited governance capacity to enforce the regulations, engages local communities and work in coordination among various government departments. Several studies reported that weak local institutions and leadership in rural areas had constrained the proper management of natural resources.

One key informant from *Wurch* agro-ecology expressed his views pertaining to the weakness of the government agents to enforce the regulations as follows:

> *…The government keeps educating us to construct and maintain conservation structures, stop cutting the trees and plant trees but some farmers are still destroying the existing trees for cropland, instead of planting new ones. Some individuals let their cattle to freely graze in the treated area immediately after installation of SWC structures, and some others intentionally destroy the physical structures by their own hands. Some farmers still allowed their livestock to graze/browse in protected areas. Nobody wants to take corrective measures for such wrong actions. We have bylaws but these individuals do not respect the bylaws.*

An additional challenge to the implementation of SLM practice is related to the mismatch in legal framework and enabling environments at the local levels. For example, the policy and implementation guidelines had emphasized the coordination between various government agencies at any levels. But this was rarely witnessed in the study watershed. Some individuals focus on their own agendas rather than depend on principles reflected in the policy, legislative frameworks and implementation guidelines of the country.

The other governance related challenge was the limited capacity and lack of initiatives by many of the assigned development agents to engage in convincing local communities instead of simply serve as an information channel to the farmers by saying "*it is a zonal and regional directives & you have to implement it whether you like it or not*". There is no doubt that processing and transmission of information are crucial in promoting SLM practices. However, since most DA's assigned to support farmers have low educational levels, they found it impossible to analyze and weigh information received from the local communities; instead they transmitted only what they received from their bosses, suggesting that the extension support services provided to enhances SLM practices was not satisfactory to relay upon. The authors tried to investigate some of the reasons why DAs do not show commitment in their duties. Almost all Development agents (who told me not to reveal their names in connection with this matter because of the fear of losing their job) stated:

> *We are not happy with the government and local authorities because we work hard from early morning to tonight but receive little benefit. As you may know, our salary is very small but our work is as hard just as donkeys. There is no more chance for further training and upgrading. All too often, chance for education, promotion to higher positions and transfer to better working places are based on poletical attitude rather than efficiency, length of services, knowledge and ability"*

It appears from the quotation that low motivation and other constraints discourage development agents to properly discharge their duties in difficult rural areas. It was also learnt from informal discussion that the majority of development agents were always keen to be transferred to areas where they perceived better and familiar with to them, which lead to their instability and frequent turnover. Without stable and committed extension services, it would be difficult to advice, build trust and mobilize the local communities for SLM practices to be sustained over the long-term.

8.1.3. Institutional Instability

One of the major challenges to curtail land degradation and promote SLM practice is frequent restructuring of institutions and turnover of the required professionals who leads natural resources management sectors. This situation results in discontinuity of experiences and actions and even loss of institutional memory. Staff turnover, mainly at *woreda* level, is common problem due to lack of appropriate incentives for motivation, good working environment, and political intervention on professional task of planning, execution and evaluation process **(**Zeleke et al, 2006).

8.1.4. Unrealistic components in rural land administration and use proclamation

Regulations frameworks and governance procedures exert considerable influence over SLM practices. Some components of the regulations are formulated by the national and regional governments but have proved inappropriate to realities in many cases. For example, though formal land redistribution is legally prohibited because of the already small size of holdings per household, the reality on the ground deviates from legal provisions, as the reallocation is seen to be a continuous process being undertaken according to informal local family arrangements. This indicates that legal minimum plots sizes are too often based on aspirations not realities that many cannot respect, forcing many farmers to become illegal.

Moreover, both national and regional land administration proclamation puts restrictions on the land use based on slope categories. For example, all very steep land (slopes>**60%)** is unstable for cultivation and should not be employed for croplands. Grazing should not be intense enough to greatly reduce or disturb the ground cover. However, very steep land is still used as cultivated, grazing or browsing purpose. This implies that some components of the proclamations did not recognize the ground realities as most of the topography in Ethiopian highlands in general and the study area in particular is characterized by steep slope where most of the croplands and grazing or browsing areas are operated on such landscapes.

8.1.5. Small Land holding size and Fragmentation

Initial land fragmentation in the study watershed was caused by one or all of the following factors. Variation in land quality was one of the elements leading to fragmentation. The interview made with one of the concerned district level official reveals that in 1990 there was land redistribution in the study areas. During the process, perceived local spatial variation in land quality was one of the major criteria for allocation of plots for legal inhabitants. Hence, to create equal opportunity, farmers were given different qualities of land at different sites which implies increases the degree of land holding fragmentation.

The last but not the least reason was the Rural Land and ministration and use Proclamations of the FDRE and the ANRS permit transfer of land holding rights to a beneficiary by will who engages or wishes to engage in agricultural works through inheritance or gift (FDRE, Proclamation No. 456/2005 &ANRS, RegulationNo.51/2007).This can be regarded as a predisposing condition for land holding fragmentation. This is because fragmentation is exacerbated where the individual transfers his holding right to a number of individuals (family members). All these situations were likely to be reinforced by the driving force of demographic pressure.

Fragmentations of land holding also result from the terrain nature of the watershed. The topography of the watershed is highly dissected which results in the continuity of farmed plots difficult. Fragmentation is worst in the lower reach and upper parts of the watershed where the topography of the area are undulating than the rest of the watershed.

Table 8. 1: Land holding size, fragmentation status and distance from farmer's home

Evaluation variable	Minimum	Maximum	Mean	Std. Deviation
size of total Land holding	0.25	2.5	0.78	0.47
Number of fragmented lands owned	1	16	4.62	2.69
Time from homestead to farm (minutes)	3	90	26.52	15.23

Source: Field Survey, 2017

In fact, there are contradictory research reports regarding whether land fragmentation[17]is a problem or not. Some study reports associate lands fragmentation with inefficient allocation of resources (time, labor and capital) leading to increased costs of production, and with the hindering of the application of SLM

[17]For this study, land fragmentation refers to the spatial dispersion of a farmer's number of plots over the watershed area and intermixed with parcels operated by other farmers

practices due to the wastage of time for the farmers spent on travelling particularly in their distant fields from the home (Hung et al., 2007; Di Falco et al., 2010; Teklewold et al, 2013). Besides, fields far away from the home are difficult to follow and guard against destruction of conservation structures by grazing cattle and wildlife.

Though land fragmentations have been condemning for such many negative impacts on SLM practices, some literature indicates that fragmented land holdings sometimes offer benefits in terms of crop scheduling; risk management and ecological variety. The arguments explain that local land quality varies spatially. Hence, farmers get opportunity to access to land of different qualities from diverse environmental zones i.e. a variety of soil, slope, micro-climatic variations) and hence minimize production risk of total crop failure due to wildlife attack, disease outbreaks and/or other natural disasters(such as hail, frosts, floods, etc.), enable farmers to grow a wider mix of crops and since crops ripe at different times, optimize farmers' schedule for cropping activities (Tan et al., 2006; Tan et al., 2008;).To date, however, there no detailed pragmatic studies made to measure the effects of land fragmentation and understanding the way through which these effects operate in the study area.

As per the views of the farmers, , land fragmentation was found to be a major challenge for SLM practices in the study watershed. A sixty-five years old respondent who takes part in this research explained challenges associated with the time-wasted and distance travelled in order to visit his scattered and fragmented land holding this way:

> *I live far from my farm, about 60 minutes on foot from that direction (pointing east). I walk this road at least two times a day. Since all my plots are spatially dispersed, I must go the same distance to other plots next day. Strictly speaking, you can imagine the work time I waste on travel and the burden in moving farm tools, inputs and outputs. Moreover, it is difficult to follow my plot's problem closely.*

Another farmer from lower reach of the watershed strengthens the drawback associated with land fragmentation by saying:

> *Land holding fragmentation decreases farmer's initiatives in participating in SWC activities. Since, his/her plots are scattered at various sites, they need to wait, probably a year or more, until the activity arrives in such site. Hence, Consensus becomes less likely to decide on where to begin and cooperation becomes more difficult as each individual farmer has their own interest and preferences.*

Similarly, a twenty-three years old young farmer narrates other disadvantages of fragmentation *as:*

Land fragmentation enhances the difficulty to protect each plot from risk of wild life attack on cropland. Farmers, who do not have sufficient labor, could not protect all scattered parcels at the same time. Hence, the risk of wild life attack on cropland would be inevitable.

Of course, the Amhara National Regional State land administration proclamation (ANRS, 2007) allows 'land holder, having acquired the right to use rural land may voluntarily exchange his plots of land situated in various localities with another land holder in order to consolidate same or find them contiguous with one another'. However, significant progress towards consolidation has not notably observed.

In addition to the typical land fragmentation problems, land scarcity also appears as one of the challenges for SLM practices. For instance, farmers partially or completely remove conservation structures thereby to increase cultivable land size and to increase production in the short run. As one 42 years old male land administration and use committee member from *Dega* area explain farmer's misunderstanding of the problems related destruction of SWC structures*:*

Formerly grass strips had always been here and there (indicating the farm). As you can see, some farmers destroyed them to expand plots, but they regret on their action when they look at erosion problems. I know there is a proclamation that insists on land users not to destruct farmland, on which their livelihood depends on, but not many us know about it and sso far there was no legal penalty made to correct offenders. As a result of these problems, soil erosions continuous, production and productivity decrease and hence the income of many farmers declines.

8.1.6. Tradition of free grazing & monkey roaming

Like that of crop production, livestock keeping in the study site is constrained by a number of factors. Shortage of grazing land and forage were reported as the main constraining factors. Grazing lands have been decreasing due to conversion of grazing land into croplands. Since grazing lands are shrinking, livestock are freely grazed in all land use types. Moreover, unreliable and seasonal fluctuations of rainfall limit the quality and quantity of fodder available and crop residues obtained.

These increasing threats and pressures on free grazing for the reason of lack of grazing lands becomes one of the main challenges to ensure SLM practices in the watershed. The government has tried to stop free grazing with rules and bylaws, and promote stall feeding in recent years albeit the management and subsequent success differs from site to site. However, local communities preferably continued their own traditional free grazing style. Though some respondents stated that it would be a good option to stop free grazing, the majority did not agree on the stall feeding for their livestock. Hence, free grazing is still the dominant grazing system in most parts of the watershed (except project assisted watershed management sites). During the dry season, arable lands become grazing areas. Due to this fact, most of the croplands are trampled by livestock until the farms are sown resulting in the destruction of SWC structures such as stone terraces and soil bunds installed on plots. Moreover, as indicated in the previous section, grazing on croplands contributes to soil compaction and reduction in the filtration rate of rain water to the soil. During the rainy season, when most arable lands are under crops, livestock are confined to graze on restricted areas such as farm strips, road sides and uncultivated hillsides.

The study revealed that the majority of farmers know the advantage of control grazing but the problem as they call it 'dark side' is lack of fodder for their livestock. Local communities believed that "*farmers cannot continue to exist without livestock"* and they think as if they have no other option to stop free grazing. The majority of them emphasized that "*livestock are money.*" In part, all these quotes echo farmer's interest to continue their habit of free grazing, which poses a big challenge for implementation of SLM practices in the watershed.

Figure 8. 1: Free livestock grazing on croplands and degraded lands **(photo: Author, Dec., 2017)**

Another challenges for SLM practices in the watershed is monkey roaming. As can be seen from Fig.8.2 monkey freely move on almost all land use types. As the result they destroying the SWC structures installed there, destroy seedling of any type planted to stablize the structures, and impede woodland formation and regeneration of trees from seedlings on the hillsides and enclosures.

One informant from *Weyna Dega* agro-ecology put the challenges this way:

> *Monkeys not only destruct conservation structures but also destroy seedling to the extent of uprooting. It's basically difficult to stop monkey ride. To put it one word, it's just a nightmare. He accentuates that despite they tried their best (the local community) they no longer able to stop monkey wandering that take place on their croplands and immediate environment (both on and around their own)*

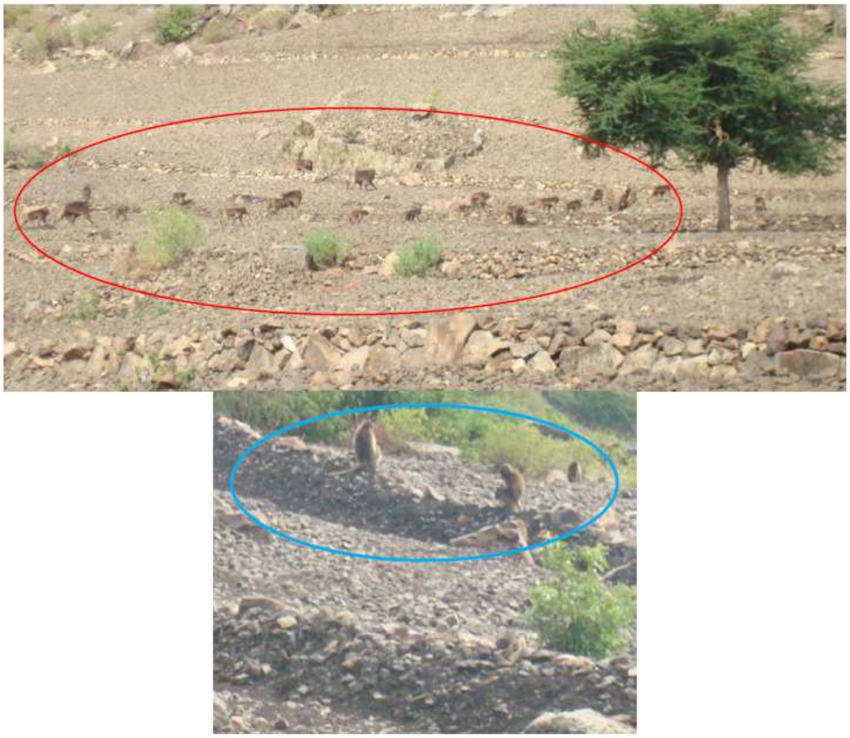


Figure 8. 2: Monkey roaming on croplands **(photo: Author, 2017)**

8.1.7. Low rates of adoption of alternative energy sources technologies

The study area, like many other parts of the country relies heavily on biomass for energy. An assessment of the fuel supply and demand behavior of rural households in the entire watershed demonstrated that biomass fuels, especially woody biomass, crop residues and animal dung, were the primary sources of fuel both during the dry and wet seasons. Although there were few farmers who depend on solar panel energy for lighting in the night time recently, there was no other significant energy substitution for the majority of households in the watershed. Most of the fuel wood used by rural households in the watershed comes from communal lands, such as shrubs, woodlots and bushes, suggesting that use of woody biomass for fuel are still a major challenge to ensure SLM practices in the watershed.

Figure 8. 3: Bundle of firewood for sale in local market (left), woodlots processing for cooking purpose (right)

Moreover, although there were some attempts to introduce and diffuse improved technologies (e.g. improved stove) for improving energy efficiency in biomass, wide scale adoption in the study area has been very limited due to a combination of interrelated factors: low affordability (poverty), lack of supply in sufficient quantity, poor distribution and marketing outlets and absence of home-based research to identify challenges encountered. Hence, almost all of the interviewed households depend on fire wood for cooking and even for night time light. This will continue to force farmers cut shrubs and bushes to satisfy their energy demand.

Figure 8. 4: **Pile of dung cake (to the left & at the middle) and fire wood (to the right) used for cooking, heating and lighting purpose** (photo**: author, 2017)**

The finding also revealed that there were differences in the pattern of fuel consumption among rural households across agro-ecological Zones in the watershed. Households residing in the *Weyna-Dega* zone mainly depends more on woody biomass mainly collected from dead trees and crop residues whereas households living in the *Dega* and *Wurch* agro-ecologies were found to depend more on animal dung. This suggests the need for agro-ecology based interventions to solve the problems of fuel scarcity in the watershed.

8.1.8. Weak coordination and absence of teamwork

The findings indicate that, in many cases, effective farmer's collaborations have been still lacking. Farmers sometimes conflict each other across their activities. For instance, poor land management practices by the land users on the upper side of the plots causes accelerated soil erosion damage at the lower plots owned by another farmers, which makes conservation efforts futile and controversial.

Other barrier to dress the persistent challenges of land degradation and implement effective SLM are weak coordination and absence of teamwork among different institutions, sectors and departments at all levels (ANRS, 2008). Although there are a number of institutions working on land management issues, most of them plan and execute their duties along sectoral lines instead of working together. This highlights the need for all-encompassing cooperation and integrated planning to bolster SLM activities

Poor integration of professional task is another challenge in the watershed. For example, there are three DAs assigned for each *Kebele* to assist farmers in specific areas such crop management, livestock management and natural resources management issues, which is an action that deserves admiration, we found that each of them usually perform all the tasks. For instance, the animal science graduate DA is often obliged to implement SWC measures and crop specific tasks in their respective *Kebele*. This could result in poor performance on tasks that require specific knowledge, including SLM activities. Moreover, the DAs are forced to be involved in many other activities outside their line of duties such as distribution of inputs, collection of tax, views of party's political program etc. These circumstances not only negatively affecting their major duties but also often put the DAs in a difficult and undefined position with the communities. This is one of the challenges that jeopardize the whole extension activities and clearly witnessed in the watershed.

8.1.9. Long-Held Local customs and culture

Customs and culture play critical role in influencing farmer's decision-making, including their likelihood of adopting technologies. Since traditions are formed over generations, it is barrier to the adoption of improved practices or new innovations. Land manager attitude which is reflected in lack of confidence in the recommended technologies, be suspicious of government agencies' advice, all act as barriers for adopting scientifically endorsed land management practices. Due to variations in such factors as education level, household size, age, gender, income level and cultivated area, there is varied degree of adoption of recommended SLM practices among local communities (Amsalu and de Graaff, 2007; Hu, *et al*. 2006).

In most SLM approaches, farmers were driven by tangible economic gains and/or incentives. It is notable that in the study watershed, most farmers participated mainly by enforcement instead of environmental consciousness and expectation of livelihood improvements. The majority of farmers have given limited attention to the dimension of the land degradation problems.

An additional challenge, related to SLM practice is the limited understanding of the community about the interdependence among various components of resources and provision of priority to one's own short-term economic security. The results indicated that some farmers did not consider the problem of soil erosion as a priority and consequently soil and water conservation was not considered an urgent option. For the majority, large farm size and repeated ploughing were considered as a strategy to increase their production, their food security status which implies the need for promotion of intensive farming system.

8.1.10. Weak DAs-farmers relationship

Although the mandate of the local institutions is policy implementation to the satisfaction of the communities, and promote people's participation in the development process, the study revealed the existence of numerous challenges in actual implementation. Local communities need institutional support from the government through various approaches. In the study watershed, support service for Promoting sustainable land management are mainly provided by the office of agriculture and rural development through development agents assigned in each *Kebele*.

Under its current organizational set up, the number of development agents within each respective *Kebeles* ranges from three to four to provide advisory services to farmers related to crop production, animal husbandry, natural resources management (TWARDO, 2017). During the field observation, the author could see an extension station within each *kebeles* in the watershed, which is a site for demonstrations, training and consultations. Nonetheless, there were a number of practical problems in relation to the delivery of the expected extension services. The level of advice given to the farmers depends on the education level of the counselors concerned. According to information provided by extension staff team leader, the education level of the majority of development agents are diploma completed or below. There were only few degree holders within the advisory section. This creates problems, because many development agents find it difficult to understand the content of the guidelines, and this makes them uncomfortable to properly imparting messages to farmers. Some farmers also blame the bias of DA by stating:

> *…the majority of development agents prefer to work with farmers with whom the site is nearest to their office and easier to travel, those who are considered as better-off farmers and who have more financial means to implement the advised technology.*

The author also noticed that the majorities of assigned DAs are younger and unmarried, who prefers not to be stationed in the extension centers of the rural areas where there is no better infrastructure but prefer to live in nearby town.

In this context, further attempt was made to include the Development agents' opinion about the most important challenges they face in everyday extension work with farmers. In the DA's view, *"Low motivation of farmers to apply the advice given, difficulty to detach from their traditional habits, lack of trust in government advice and bad infrastructure in rural areas",* were some of the challenges mentioned. One development agent from *Wurch* area explained the persistent challenges he encounters as:

> *…Despite many campaigns and several platforms to steer implementation of SLM activities, the majority of the farmers did not want to be involved in or to seek assistance from us (Development agents). These farmers preferred to rely on their own experience. They prefer conventional methods of growing crops and consider us having no practical agricultural experience. There are only a few progressive farmers, who likely to adopt new land management approaches, particularly those involving in SLM program project and productive safety net programme".*

The DA's explanation implies that changing the mindset of farmers is difficult and believes that farmers' indigenous knowledge cannot solve their problems. Though as to whose reality holds true calls for further research, the Author is doubtful whether the DAs are better than the farmers who have developed long life experiences about their environment and their plots.

In contrast to DAs view, many key informant farmers noted that top-down impositions and command type of approach were common under a false piety of popular participation in the platforms of public meetings. As confirmed by many key informant farmers, there was no space for the farmers to express their feelings and problems to act upon agreed points. They complained that advice from development agents did not yet benefit them. The majority of farmers from all agro-ecological zones stated DA's advice as *"it is simply talk, they didn't bring anything new in our life*". They further explained that *"DAs tell us what we already know and they impose their own interest instead of considering our problems and opinions*". As one key informant from *Wurch* agro-ecology further stated: "*DAs act as if they alone know all the best for us"* while dealing with our local problems.

Nevertheless, some farmers particularly from *Wurch* zones of the watershed did not deny the efforts made by the development agents to create awareness about the benefits of SLM practices in their respective sites. As they further stated *"had it been we followed the advice given, our land might not be in danger. It is our weakness to accept their advice*". These imply that farmers' interest to look for aid and development agents' commitment to discharge their duties varies from site to site based on socio-economic contexts. Hence, to properly address the problems, it is advisable to fill such gaps instead of following "one-size-fits-all" approaches to deal with the challenges. All these suggest that it is imperative to carefully consider the training and advisory services approaches as outlined on policy directives and sustainable watershed/land management guidelines. It is also important to complement scientific knowledge with the relevant local knowledge as SLM practices through instructing and controlling approach could be mere imagination. The Author suggests that development agents should live and work among and with farmers and they should be familiar with farmer's practice, social structure, problems and aspirations instead of following the old-fashioned practice of telling farmers what to do.

8.1.11. Farmers' dependency attitude and lack of commitment

Dependency syndrome is one of the major factors that affect sustainability of land management schemes. Work for Food and other incentives can be a positive tool, but it can also be negative because dependency may reduce the individual's voluntary initiative to participate in local resource management activities, such as those required to prevent land degradation and promote SLM practices (Berhanu, 2000; Zeleke et al, 2006; Little, 2008). In the study watershed, many interventions made so far at the landscape and farm levels were not sustainable due to linkage of land management/SWC activities to the Food for Work

Program; wrong way of incentives and other related factors. Farmers were asked whether incentives and subsidies are required in the form of food or cash to become involved in SLM practices, though the proportion varies all of them responded that they need to get some incentives. In *Wurch* agro- ecology, the majority of farmers believe that they can't live without aid of any kind. The reasons given included the food shortage due to recurrent drought and some believed that incentive is mandatory as the task is the responsibilities of the government. Hence, due to this disposition, they are reluctant to accept any development interventions including SLM practices because of the fear that they will lose the aid. It is evident that farmers who seemed to accept SLM practices in the occurrence of incentives, gradually stops its implementation and even ultimately start to destruct conservation structures installed on his/her plots when the incentives stopped. This circumstance was also reported by Shiferaw and Holden, (1998) before twenty years back.

The study also revealed that farmers were more motivated if there were incentives. For instance, in PSNP approach, participants were provided support either in kind or cash for the labor they contribute in public works such as SWC, water management, and road construction and maintenace. If they do not abide by the rules, their financial support payments will be reduced or totally stop. Hence, they have been always found in a frontline for any SLM related community campaign work.

Contrary to this, those who were not beneficiaries complained that any watershed management activities could be the responsibility of safety net program beneficiaries. The complaints justify that unless they equally shared the incentives, they will not be interested to participate in any public work. They further reasoned that they have equal access to land. They have also equal opportunity and challenges in the area. Hence, it is not logical to favor some asbeneficiaries and neglect others. How long we "*watch those who eat*". These opinions suggest that there is an inclination towards incentive among the majority of the farmers but partial incentives discourage the motivation of non beneficiaries to participate on SLM practices in the watershed.

Moreover, though community members agreed through local level indigenous community bylaws on common resources management, governance and utilization arrangement, the agreement reached by the communities were not respected by some the community members. For example, though communities developed rules and regulations to control free grazing on area closures and extract resources such as fodder grass, fuel wood and wood from woodlots by each member on agreed time and modality, successful implementation on utilization arrangements were not sustainable due to frequent failure to abide by commonly agreed terms.

8.1.12. High poverty and limited alternative livelihood options

There strong linkage between rural poverty and natural resources exploitation *(WCED,* 1987). Poverty not only forced the poor people overuse environmental resources for their survival and livelihoods but also restricts household ability to make resource-enhancing or conservation investments.

While sustainable land management leads to poverty alleviation, the deep-rooted poverty leads to land degradation as people over dependence on existing land resources for livelihood which in some instances has undermined the capacity of the rural communities to manage their land resources properly and sustainably. Resource poor farmers often impose unsuitable systems of land use which quickly result in land degradation (FAO, 1999). Similarly, Pimentel (1993:11) substantiate this argument as "*Subsistence farming in itself is an impediment to conservation. Resource poor farmers often find it difficult to invest in conservation-effective practices even if they are aware of their benefits*".

Poverty also forces many resource users to focus on short-term coping strategies rather than long-term investment in land resources. These problems were more visible in the study watershed where degradation of local natural resources makes the poor more vulnerable to poverty. Accute shortage of crop and grazing lands leads to the invasion of marginal lands and unsustainable land use practices that in turn encourage environmental degradation Vicious downwards spiral.

As indicated in chapter three, almost all of the population living in the watershed primarily depends on agriculture for their livelihood, and a similar percentage depends on local wood resources for energy sources and construction.

Moreover, the overwhelming majority of the households at the watershed are neither food self-sufficient nor food secure as explained by lack of access to sufficient land, vulnerability to frequent drought, insufficient capacity of institutions to properly implement rural policies, and the failure to properly utilize the available natural resources at household or individual level. This was evidenced from safety net beneficiaries and direct food aid recipients. For instance, one respondent from *Wurch* agroecology disclosed his state of poverty as *"I am living in an empty house; I am just living above the dead and below the living"*. This evidence contradicts with the report which shows the rising trend of farmers' incomes and livelihoods in the watershed. From the message, it is also clear that failure to take into account people's livelihood strategies may result in lack of interest to engage in resource management related activities.

These poverty traps are most likely responsible for unsound land management practices leading to low land productivity and poor management of the farming system. Although several sustainable land management options exist, their uptake was quite low. This was mainly because of the subsistence nature of farming; farmers give more importance to their immediate needs than to the long-term benefits. Consequently, investments in SLM practices may not be on the minds of the farmers' priorities. Thinking about tomorrow may not be their concern. This suggests that the poverty reduces farmer interest to take action to protect land as they give priority to activities related to their immediate food requirements.

8.1.13. Farm labor shortage and wrong scheduling of public works

The reasons for the shortage of labor are due to the following: In the past, children used to play a significant role in household farming activities including bund construction and taking care of the livestock. However, this role has declined over the years as majority of the children in the study area, including the girls, are now going to schools. Thus, it is beyond the capability of the remaining adult household members, who are already over burdened from all kinds of farming activities.

Most youth of the watershed do not have access to rural lands (even those who have access, don't have sufficient plots). Hence, they have to choose either working on the family land or leaving the household. In fact, the majority of rural youth do not want to stay under their parent's authority in rural areas; instead they opt for off-farm activities or migrate to urban areas to develop their livelihoods. As a result, rural-urban migration becomes an increasing threat that deprives labor forces from the rural areas. This leaves the rural villages as home for only the older generation. This implies that such old farmers are unlikely to be keen on implementing labor intensive SLM practices, particularly construction of SWC structures due to shortage of labor. For example, for construction of stone bunds, most farmers have to travel long distance and collect stones suitable for the purpose. Moreover, stones are normally carried on the shoulder due to lack of any means of transportation, making the task very difficult and time consuming.

8.1.14. Gender-based divisions of roles

In the nearly few decades, several attempts have been made to promote gender equality and empower women into natural resource management programmes in Ethiopia. For example, watershed management proclamation of the Amhara Regional State enacted: *"any watershed administration and use process, shall have a balanced composition of gender and females shall be given equal opportunity, in accordance with their capacity"* (Proclamation No. 204/2013, article 32 sub-article 1-2). Sadly, however, much of this seems remained restricted to the paper. The existing traditional cultural norms and practices still constrain the actual implementation of the principles of promoting women's participation in resources management activities. The patterns of gender divisions of labor and the gender-based differences in roles with respect to decision making and action in land management issues have been clearly visible in the study watershed. While women are generally responsible for all decisions regarding domestic issues along with assisting in agricultural operations, men are concerned with land management issues outside the domestic sphere. Many of the respondents attributed the gender discrepancy to the fact that men are expected to shoulder the responsibility for formal decision making with respect to maintenance and management of land resources and therefore discourage women's from participating in meetings (keep silent even when present) and overall land management activities, leaving the responsibility largely to the men. This implies that progress in women participations in the watershed are still low despite an enabling policy, legal environment and watershed management principles that underline women's participation as one of the basic requirements.

Since rural women maintain an intimate interaction with natural resources, their experience gives valuable information required for the management of the environment. For instance, women play roles in collecting water and gathering biomass for fuel, hence, their experience and knowledge are vital for environmental management. Because of such important contribution of women, the fight against the degradation requires a gender-inclusive approach. Therefore, a lot has to be done beyond mere lip-service and tokenism to break the cultural barriers and promote meaningful participation of women in resource management activities in the watershed.

Sfinally, government actors (e.g. *woreda* experts and development agents) involved in SLM were asked to specify encountered challenges to promote SLM in the watershed. Competition over common property resources and lack of interest for better stewardship of these resources, epitomized by the concepts behind the "tragedy of the commons" (Hardin, 1968); inadequate institutional, human and financial resources for capacity building and extension services; low working culture, poor management of SWC structures & lack of will to maintain it; absence of incentives for committed individuals; lack of commitment/ self-motivation among community members, divided interests and lack of alternative livelihood options; farmer focus more on livestock number than on quality and productivity and shortage of technically skilled technicians to oversee design & operation of the SWC structure were mentioned as key Perceived barriers.

8.2. Prospects of SLM practices in Gedalas watershed

Previous interventions to combat land degradation and rehabilitate degraded lands have left some precious experience and many prospects behind. This implies that proper use of these opportunities should be the spring board for successful SLM intervention decisions. The intent of this section is to briefly review key prospects that will help to promote successful SLM practices.

8.2.1. Presence of enabling policy environments and legal frameworks

As it was indicated in chapter two, the government recognized the need for sound policies, both national and regional governments understand that the sustainable land management requires participatory, integrated and coordinated approaches, and concerted efforts at all levels. These government policies and programmes can influence farmers' decisions on SLM activities. Although the threats and pressures on land degradation are still apparent, the future of the watershed looks promising if the existing environmental policies, programs and implementation guidelines are properly implemented. Some of the existing legal framework for the implementation of SLM practices includes:

8.2.1.1 The Constitution of Federal Democratic Republic of Ethiopia (Proc.No.1/1995)

As the supreme law of the land, contains provisions which recap the importance of the protection of the environment and the need for its proper management and sustainable utilization. These provisions laid out the foundations for subsequent legislations in the environmental protection, rehabilitation and management actions (FDRE, 1995). For example, Article 44 (1) of the constitution guarantee "*the right to live in a clean and healthy environment*" and Article 92 (1), in its environmental objectives, pledges that "*the Government shall endeavor to ensure that all people live in a clean and healthy environment*" and all citizens shall have the duty to protect the environment. Furthermore, Articles 89 and 92 of the constitution oblige national policy and government activities to be compatible with environmental health (see FDRE, 1995).

The constitution also provides for the decentralization of natural resources management responsibilities to local governments and underlines consultation and community participation as indispensable elements of development activities. The argument for decentralization lies in the assumption that local governments possess greater knowledge of the local needs and have more information on locally feasible actions. For instance, Art.51 (5) of the constitution authorizes the federal government to "…. *enact laws for the utilization and conservation of land and other natural resources….*" and Art.52 (2) (d) authorizes the regional states to "…. *administer land and other natural resources in accordance with federal laws…….*" (FDRE, 1995).

8.2.1.2 The Environmental Policy (1997)

It provides overarching environmental policy framework and guiding principles for sustainable management and utilization of the country's natural and environmental resources and clearly outlined the sectoral environmental policies, relevant to environmental management such as management of soil, vegetation, water resources and maintaining ecosystem biodiversity among others (Nyssen et al., 2004; Bekele, 2008). The policy stipulates the importance indigenous tree species for afforestation/reforestation practices. The environmental policy also consists of other policies in some crosscutting areas such as population and environment; community participation and empowerment in environmental management activities; tenure and access rights to land and natural resources; land use plan; social and gender issues; environmental economics; environmental information system; environmental research; environmental impact assessment; and environmental education and awareness.

8.2.1.3 Rural Development Policies and Strategies (2003)

The content of the policy document clearly stipulates the need for proper land use and management based on agro-ecology. It highlighted that proper land use is necessary in all realms of private and commercial activity in order to maximize the economic return of the land. It notes that any misuse of land resource will encumber the development of the country.

8.2.1.4 Ethiopian Strategic Investment Framework for Sustainable Land Management (2009-2023)

The importance of SLM has increasingly been recognized in national development plans and poverty reduction strategies. The government has approved and is implementing a National Programme Framework for SLM which has been planned to be implemented in three-phase five-year plan (2009–2013, 2014–2018, and 2019–2023) with the overall goal of "*providing an integrated holistic framework to effectively address poverty, vulnerability, and land degradation in order to improve the livelihoods of land users while restoring ecosystem functions and ensuring sustainable land managemen"* (FDRE, 2012). The programme sets key priorities for SLM investments, sets out a strategy for scaling up SLM based on best practice lessons, and defines the approach and mechanisms for coordination, consultation, participation and monitoring and evaluation. In its environmental objective, the investment plan reiterates the need for rebuilding natural capital assets by overcoming the causes, and mitigating the negative impacts, of land degradation on the structure and functional integrity of the country's ecosystem resources. It propose that successful interventions to address land degradation and climate resilience require integrated and cross-sectoral approaches that often involve locally specific combinations of land use practices, structural and biophysical land management measures, infrastructure, watershed planning and development, livelihoods enhancements, crop and livestock management, forest management, and a strong participatory element (World Bank, 2008; MoARD, 2010). It was part of these efforts that the study watershed has been selected as one of the pilot sites for the implementation of SLM program in combination with other income-generating activities.

8.2.1.5 The Federal Rural Land Administration and Use Proclamation (*No. 456/2005)*

The Proclamation confers indefinite user rights including rights to property produced on the land, rights to intergenerational tenure transfer and provision for the registration and certification of tenure rights to strengthen tenure security. The proclamation specifically addresses the issues land degradation through obligations of land users to sustain the land, imposes restrictions of farming and free grazing on sloppy grounds (slopes above 60%); restrictions on the use of wetland areas and land dissected by gullies and protection of wetland biodiversities. This Proclamation also has provisions indicating that there will be no further land redistribution, except under special circumstances (FDRE, 2005). Moreover, land administration has decentralized into the regional governments and offered power to have their own land Administration and Land Use Proclamations. All these create a conducive atmosphere for proper land use ensuring that the management, administration and use of rural land in the region is carried out according to established laws and regulations.

8.2.1.6 Growth and Transformation Plan (GTP I and II)

These plans have underlined the importance of environmental conservation as an imperative constituent of sustainable development and emphasize the need to build a carbon neutral and climate resilient economy. For instance, in GTP II document, it states that in order to transform Ethiopia to the status of middle-income country by 2025, the government outlines the need to intensify the ongoing implementation of participatory integrated watershed management by taking into account the unique conditions of varying agro ecological zones (NPC,2016). It recognized the importance of green economy strategy as its key environmental direction to undermine the impacts of climate change, environmental degradation and biodiversity loss on the required economic growth.

8.2.1.7 Community-Based Participatory Watershed Development Guideline

Issued by the MoARD in collaboration with WFP, USAID, GTZ, ILRI, etc since 2005, the guidelines elaborate principles, strategies, procedures and steps for the effective implementation of the watershed management activities and provides very detailed standards on how to design and implement activities for the realization of the strategy within watersheds. The guideline was formulated in response to the failure of the previous soil and water conservation efforts in the country. The main objectives of the guidelines are establishing effective and common approaches for community-based planning for natural resources development, selection and implementation of suitable technologies under different agro ecological conditions and identification unexploited and/or undervalued potentials in the watershed. The guidelines also point out the importance of promoting full community participations (men and women, land owners and landless) and joint decision making at all levels of watershed management activities (planning, implementation, monitoring and evaluation). It also stipulates multidisciplinary, multi institutional and multiple interventions approach (Desta et al, 2005).

8.2.1.8 Decentralization of authority

Even though decentralization is sometimes blamed for its danger of empowering the local elites at the expense of local communities and continued existing poverty and inequality (Johnson, 2001), it is believed that devolution provides power and authority to local communities for managing natural resources (Ayenew et al., 2007). It was against this background, for instance, the ANRS enacted legislations for the measurement criteria for watershed users, rights and duties of watershed users, protection, administration, management and use of natural resources in the watershed (ANRS, proclamation No. 204/2013, article 8 sub-articles 4) modeled after the federal legislations. These legislations further devolving to the *Woreda* and *Kebeles* levels. Thus, the *Woreda* and *Kebeles* have become the ‘front lines’ in efforts to the implementation of SLM practices. All these will create an ideal opportunity for the implementation and success of SLM practices.

8.2.2. Ecological diversity of the watershed to test various SLM options

SLM activities are affected by complex array of factors including diverse agro-ecological settings and socioeconomic conditions. The study watershed has a highly diverse agro-ecological environment that range from *Weyna-Dega* to *Wurch* agro-ecologies. This ecological variations creats favourale conditions for testing of a wide variety of SLM technologies and practices in different combinations instead of applying a one-size-fits-all set of interventions which is unlikely to work effectively across the watershed.

Moreover, this agro-ecological diversities is not only important to test various SLM options, but also it is crucial to produce diversified crops in different parts of the watershed which ranges from barely in the *Wurch* zone to maize and sorghum in the *Weyna-Dega* zone..

8.2.3. Community degraded land management experiences through enclosure strategies

Establishment of enclosures in steep, eroded, and degraded hillsides which have previously been used for grazing and browsing area is promising practice to rehabilitate and reverse degraded areas. Planting of seedlings such Eucalyptus has its own benefits for the rehabilitation of degraded landscapes and wildlife conservation. Enclosure can be viable systems if it has clearly defined users, boundaries, and locality-specific regulations on use and management responsibilities (Mengistu et al., 2005).

8.2.4. Ecotourism promotion and development

The watershed has greater prospects in implementing wildlife conservation, development, and research and education programs. The watershed is rich not only in variable landscapes with various afro mountain plant species but also endowed with endemic wildlife resources which may serve as destination for tourists. For instance, a good number of chilada baboon & semen fox have currently live in the watershed. This is a potential for promoting ecotourism in the area. Likewise, the recovery of “Guassa” grass in the upper reach of the watershed becomes a good potential for generating job opportunities, disposable income and improve standards of living of the local communities. Hence, if this area is properly managed it will have significant contribution not only for the ecosystem and biodiversity of the watershed but also to improve the livelihoods of local community through ecotourism development.

8.2.5. Experiences gained from SLM project

The study watershed was one of the pilot sites for SLM projects. The overall goal of SLMP is to “*provide an integrated holistic framework to effectively address poverty, vulnerability, and land degradation in order to improve the livelihoods of local communities while restoring ecosystem functions and ensuring sustainable land management*” (MoARD, 2008). With the support from the World Bank and other donors, Project implementation was in progress in the watershed at the time of data collection for this study (2016-2018). Though it was stared very recently and its total area of intervention was limited, the project in the study watershed had been working to minimize rural poverty through restoring degraded lands, sustaining and enhancing bio-diversities and improve local livelihoods in the watershed. Hence, experience gained in integrated watershed and landscape management technologies and approaches; institutional strengthening, capacity development and knowledge generation techniques will play great roles not only to effectively implement in the site but also to up scale the experiences gained in the watershed to other areas of the district.

8.2.6. Land registration and use right certification

As evidence from both theoretical and empirical literature indicates, land tenure security is anticipated to improve investment. Therefore, land certification is expected to enhance tenure security and thereby to increase sustainable land management practices (Besley 1995; Deininger and Castagnini, 2006). Under the current constitution of Ethiopia, land ownership is exercised by all the people through the State, which is the representative of the people. The constitution states: *"The right to ownership of rural and urban land, as well as of all-natural resources, is exclusively vested in the State and in the peoples of Ethiopia".* These Constitutional provisions have been further strengthened by both Federal and regional proclamations and regulations issued on rural land administration and use issues.

Land resource has been and will continue to be an important means of production and livelihood security in the study watershed. In the study area, the number of landless youths is and the need for owning agricultural land for agricultural production is constantly increasing while the cultivated land area shrinks. To address the problem local governments have started to allocate steep mountainous lands with or without bench terrace as an alternative for annual crops and fruits production. Such a situation seems to create a strong pressure on further redistribution of land in order to best serve the interests of the youth in the community.

Nevertheless, focus group discussions were held with group of local communities to understand their views on land tenure. They were asked to state their views whether or not their current land holding stay with them or not. The results of the discussion revealed, though the youth and other community members who do not have land believed in future land redistribution, the majority of farmers have believed that there will be no land redistribution in the near future. They confidently replied that since they already have land use certificates, they not hesitant losing their holding in their lifetime so long as the current government remains in power. This clearly implies that investment decisions in sustainable land management practices, including tree planting will not be constrained by tenure insecurity in the watershed. This agrees with finding of Bewket and Sterk, (2002) in Northern Ethiopia, who noted that land ownership does not hinder farmers' SLM practices.

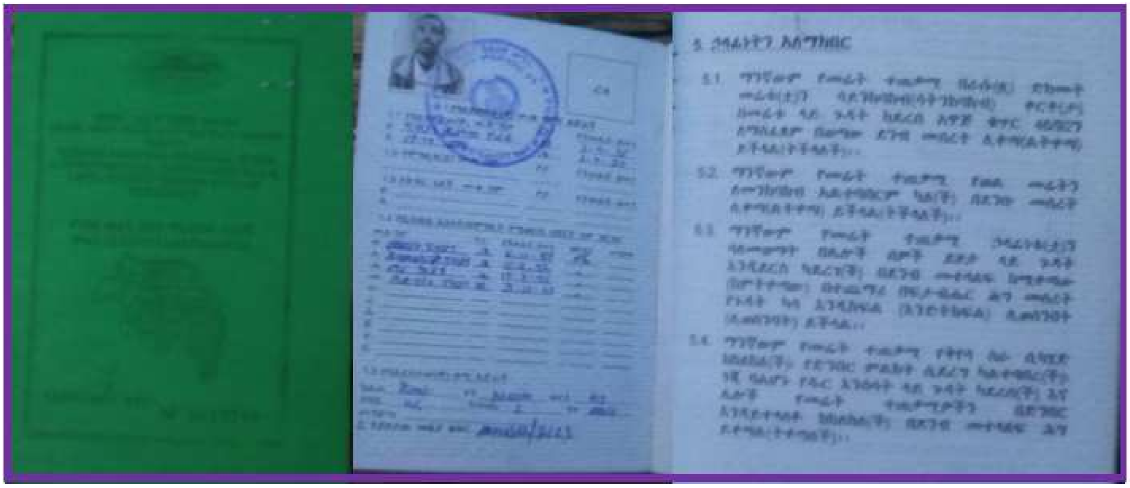


Figure 8. 5: Book of holding with description of parcel information, list of family members, farmers' rights and responsibilities

8.2.7. The Establishment of Mekdela Amba University adjacent to the Watershed

One of the missions of higher institutions is provision of community services. Hence, Mekdela Amba University, which was established recently near the watershed, is expected to play great role in identifying local problems through its community services and research activates. The university will provide advisory services and in-service technical training to build capacities within the government institutions and improve the knowledge and skills of local experts, so that they in turn can transfer technologies (including SLM measures) more effectively in the watershed and promote their wider use by the farmers themselves to secure their livelihoods for the long term.

Summary

Although the government of Ethiopia attempts to reduce land degradation for decades, the problems remain challenging due to multiple interlinked environmental and socio-economic factors. Some of these key barriers which negatively impact on the success of efforts made for achieving SLM include: failure in understanding geographical disparities while recommending technologies, top-down manner of planning and implementation approaches, inflexibility of the proposed solutions, farmers' lack of livelihood opportunities outside the farming activities, inadequate consideration of farmers' opportunity cost of time, limited interest and capacity of farmers to make SLM investment, lack of capacity and awareness of institutions to properly implement existing polices, strategies and implementation guidelines, institutional instability/ frequent restructuring, disregard of to recognize the significance of local knowledge and practices, limited capacity and lack of commitment by local Government, climate change and variability, inadequate integration of farmers' own experiences and preferences, to mention but a few.

CHAPTER NINE

9 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction

In Ethiopia, movement to prevent the peril of land degradation has begun in the 1970s. However, until 1990s the activities were devoted towards reducing soil erosion rather than enhancing rural livelihoods. The implementation approach was more of a top-down (government-mobilized) and incentive based (food-for-work) with limited participation of the community. Since the mid of 2000s, SLM through community-based integrated natural resource management approach was introduced to simultaneously address the triple objectives of economic growth, social equity and environmental sustainability within prevailing agro-ecological and socioeconomic environments. With these in mind, this research set out the status and prospects of SLM practices in Gedalas watershed of the Beshillo catchment, Blue Nile Basin, Northeastern Ethiopia. In the study, five specific but related themes were pursued in the watershed: the state of land use/ cover dynamics; soil loss rates; soil physiochemical properties; ongoing SLM activities as well as sustainability prospects using holistic research approaches complemented by more detailed specific research methods which reflects on human-environment interactions guided by DPSIR and Sustainable Livelihoods Frameworks.

The following sections and subsections summarize the study, highlights conclusions arrived at and suggest recommendations based on study objectives and the associated research questions of the study.

9.2. Executive Summary

The overall finding of this study revealed that unsustainable agricultural practices, persistent soil erosion, poor soil nutrients status, frequent drought, poor water management practices, poor agricultural productivity and serious food security challenges are some of the main current feature of the watershed. Faced with declining yields, farmers in many areas of the watershed typically seek new land to clear for crop production. Unsustainable destruction of vegetation covers and the conversion of environmentally fragile lands to crop production and livestock rearing pose difficulties in achieving long-term economic development and food security goals, and often contribute to the ongoing environmental degradation.

It is apparent that the government intends to deal with SLM practices through integrated land management strategy. For example, along with many natural resource management policies and programs *reforms in the last decade*, the government has prepared specific implementation national guidelines for SLM through integrated watershed management approach since 2005 (Desta et al., 2005). This reflects the government's commitment to promote SLM practices. However, though national guidelines for SLM are in place, it remains challenging to implement on the ground.

The first objective of the study was related to LULC issues with the assumption that LULC status of the watershed is intertwined in many ways with other environmental attributes, including but not limited to, soil fertility, soil management for sustainable agriculture, local climate, prevalence of biodiversity, and provision of safe drinking water to list but a few. Change in LULC results concomitant changes in these environmental variables. Thus, systematic examination of the status and trends of LULC dynamics in sustainable land management studies has paramount significant as an indispensable indicator of environmental changes.

With this in mind and pursuant to the objective one, assessment of historical and current LULC state of the watershed were under taken by integrating historical and contemporary data sources compiled from remote sensing archives and augmented by local perceptions.

The result demonstrated seven major LULC classes and the overall scenario presented by the study reveals that the watershed has experienced quite visible LULC transitions that seem to be continued in the future due to eternal anthropogenic activities and natural factors. The study revealed that though there were changes in all land use types, the major change detected was a consistent expansion of farmland/settlements area mainly at the expense of Afro/sub Afro alpine vegetation areas. On the contrary, Afro/sub Afro alpine vegetation showed a consistent net loss of over the study periods. Expansion of cropland is and was the leading alteration in the watershed, as most of the inhabitants profoundly relies on this sector as a solitary livelihood option. The study suggests that if these trends of crop lands expansion allowed continuing, sooner or later there will be no Afro/sub Afro alpine vegetation will remain. Perceptions of the local communities on LULC change trends substantially agree with data from satellite images. Their perceptions highlighted that afro/sub afro alpine vegetation cover of the watershed have been drastically declined over the last four decades despite they did not deny the recent restoration efforts.

The findings also highlighted that transitions were ultimately driven by the interplay of biophysical, socioeconomic and institutional factors, including terrain characteristics, population growth and associated economic motives, recurrent drought, use of biomass for fuel energy, livestock pressure and change in government policies. Moreover, changes in government regimes and associated policy shifts in the country have had opened up space for local LULC changes (Chapter 4).

Water induced soil erosion is one of the major challenges in the Gedalas watershed of the Beshillo catchment. The watershed is typical of the northeastern highlands of Ethiopia, where cultivation on a steep slope has a long history. In pursuant of the second objective, an attempt was made to estimate the magnitude of soil loss rates under current land management practices and land use/cover scenarios in the watershed (Chapter 5). The study employed RUSLE model to estimate quantitative soil loss values and local perceptions to complement model results and to evaluate on how farmers perceived the problem in the watershed.

The study not only quantified average annual soil loss value under current conditions in the watershed but also mapped the spatial distribution of soil erosion prone areas using RUSLE model in GIS environment. The values of estimated erosion ranged from 0 to above 935 t/ha/yrs. The average annual soil loss value was found to be 37 t/ha/yrs, which significantly exceeded the soil loss tolerances limits for Ethiopian highlands. Although, in most cases, very slight soil loss level tends to dominate, extreme and very extreme soil erosion was not uncommon for large parts of the watershed with poor vegetation cover, bare lands, and steep slope mountainous areas. It was found that more than 7.7 % of the total area of the watershed experienced very severe erosion rate. The study implies that if the process is not unabated, these parts of the watershed will be degraded beyond economically feasible restoration.

It is apparent from the spatial distribution map that the topographic factor had the highest contribution for the high rate of soil erosion suggesting that slope management is the most important task in preventing the soil erosion by water, and the soil conservation activities should be in accordance with the contribution level of these factors. The study also revealed that the lower and the top reach parts of the watershed have the highest erosion prone areas and thereby with the highest priority for soil conservation measures. The result also implicates the need for diversification of livelihood activities in the watershed where cultivation on steep slopes has become the common practices because of population pressure and associated land shortages.

The model result was verified with local perceptions and field observations and the result signifies that soil erosion rate estimated on the watershed matches well with the community perceptions for the study watershed suggesting farmer’s broad knowledge to identify soil erosion problems, indicators, and causes of soil erosion in their locality. Their perceptions fairly agree with several empirical scientific literatures. Tackling soil erosion, therefore, requires the integration of farmers' knowledge and experience on their localities rather than prescribing solutions, which farmers may not view as feasible and important(Chap.5).

As a final point, the study demonstrated that integrated RUSLE, GIS and remote sensing techniques are vital approaches to estimate soil loss values, identify and delineate erosion prone areas over the watersheds, and provide decision support evidence to prioritize the areas for effective planning of sustainable land management based on erosion severity levels. Nevertheless, it is imperative to remind that the estimated soil loss values might not be completely free from errors because of the inherent limitations of the model (Morgan, 2009).

Crop and livestock production are major human activities on the Gedalas watershed. Hence, soil fertility is important components for crop and livestock production and crop quality, environmental quality, biodiversity and nature development, as well as for resource (land, water, energy, fertilizers) use efficiency. Despite its importance, little is known about spatial and temporal variations in soil fertility of the study watershed.

LULC change to crop production and continuous and intensive cultivation of soils with very low inputs have been practiced in the study watershed over thousands of years as elsewhere in the country. Population pressure has also led to cultivation of marginal lands and steep slopes. Soil erosion is still severe problems particularly in sloping areas and where vegetative cover is very low and soils are already very shallow.

The third objective was analysis of the status of major soil physico-chemical parameters under selected LULC types and agro ecologies in the watershed. Soil property testing is indispensable approaches in understanding the spatial variations and elucidating land use problems originating from soil conditions which are not directly observed in the field. Assessing the status of soil properties is also vital to understand the status of soil qualities and as to how land degradation-rehabilitation dynamics have impacted on the soil status of the watershed. In addition, soil analysis is significant to diagnose the nutrient status of the soil for determining the fertilizer needs and thereby maximize crop production by the rational use of the required inputs in combination with the application of other up to date management practices.

With this background, selected soil physicochemical parameters of surface soils (0-20 cm) were analyzed on different LULC types and agro ecologies following standard procedures. The findings indicated that most of soil mean values of physical and chemical parameter values in the watershed were within or just below the optimal ranges and significant differences where apparent on some of these properties both among LULC categories (ex. Organic Carbon, Total Nitrogen, Cation exchange capacity, Exchangeable Calcium and exchangeable magnesium) and agro-ecologies (ex. texture & soil pH). This implies that shifts in land use/covers across the watershed and variations in altitudes are likely to have important impacts on soil functioning (Chapter 6).

The most important soil attributes in cultivated lands showed an overall change towards the direction of loss of its fertility compared to the adjacent shrub and grassland soils. These variations of soil physicochemical properties among LULC types implicate the risk to the sustainable crop production in the watershed. The process of prolonged use of lands for crop production with no or only little inputs has exacerbated soil quality decline leading to soil degradation, which may ultimately lead to complete loss of land values. Therefore, SLM provides options to improve management of the soil resources.

The fourth and fifth objectives of the study were to figure out the current status of SLM practices, implementation approaches, management activities, the level of community participation, outcomes on biophysical environments and local livelihood (supported with detailed case studies) (Chapter 7); and various challenges and barriers to sustainability that are specific to Gedalas watershed (Chapter 8). The study also attempted to evaluate how land management policies, proclamations, strategies, and implementation guidelines were being translated into operational practice and the extent to which realities depart from these legal frameworks in terms of implementation approaches vis-à-vis present land management scenarios. For this effect, variety of data collection methods were employed, including scheduled and key informant interviews, focus group discussions, interactive on-farm walks, participant and non-participant observations, and document reviews. Moreover, theories of literature were reviewed to identify and organize the set of challenges by focusing on both academic papers and other literatures.

The key findings of the study show that through most of SLM interventions have focused narrowly on soil erosion control measures such as cross-slope barriers in the form of terracing across agro ecologies and land use types, other supplementary land management practices such as hillside closures, drainage ditches, application of chemical fertilizers and the spreading of organic manure were also identified in limited extent.

Furthermore, community participation in the SLM activities was found to be unsatisfactory and many of the activities were practiced involuntarily. In this regard, several factors were identified. Among variables considered in this study, total livestock units, use of hire labor, access to land management advice, credit access, participation in project and safety net program, perception on the importance SLM practices and holding land use certificate were found either singly or in combination influence positively and significantly farmer’s decision to implement SLM practices, while expectation of drought incidence influence significantly and negatively. The study also shows mixed findings on the outcome and performance of SLM practices on biophysical environments and local livelihoods. Thought it was not felt intensely by all farmers, it was observed that in the SLM program of pilot micro watershed sites which were supported by SLM program project, the SLM outcome and community participation were relatively encouraging in comparison to the non SLM program watershed sites. This is because of better awareness creation program and provision of incentives.

The study was tried to assess sustainability challenges and prospects for promotion of SLM practices in the study watershed. The most commonly identified barriers that jeopardize the success of SLM activities in the watershed included: recurring drought and long term dry spells, free grazing practices, low rates of adoption of improved technologies by the community, in biomass energy, weak institutional support, poor integration of professional tasks and weak farmer collaboration, long-held traditions, farmers’ dependency attitude developed from previous food-for-work program and lack of motivation among land users, farm labor shortage and wrong scheduling of public works, gender-based divisions of roles poor technical advice and low quality of technical work, poor consideration of the local context, lack of genuine community participation and wrong implementation approaches and others. Despite all these challenges, presence of enabling policy environments and legal frameworks, ecological diversity of the watershed to test a wide array of SLM options, opportunities for ecotourism promotion and development, experiences gained from SLM project and the land registration and use right certification provide opportunities for success.

9.3 Conclusions

From the study and the preceding summary the following conclusions are drawn:

1. Land degradation is unsolved and pervasive problem in the watershed

Agriculture plays a crucial role in producing food stuff and sustaining livelihoods for the ever-increasing population of the study watershed. However, due to ever-increasing pressure on natural resources, various key indicators of land degradation have been observed. Though the project intervention sites of the watershed were better in pursuing SLM practices compared to non-project implemented watershed areas, this study reveal that land degradation problems are still the major challenges in the Gedalas Watershed. This is evidence from the overall undesirable land use/cover changes, high soil loss rates, soil nutrient depletions, increasing trends in application of agro-chemicals (chemical fertilizers), increasing dependence on external aids, and limited success of land management efforts among others. As indicated by the respondents, production and productivity has been gradually declining. Growing population pressures have led to expansion of agricultural land and high demands for fuel and construction wood. Furthermore, uncontrolled grazing in the grasslands, croplands and hillsides are common and endangers the SWC activities implemented in the watersheds. Such interlocked and complex problems put the sustainability and prospects of land management practices under challenges.

The study also revealed that though most farmers residing in the watershed are aware of the land degradation problems, causes and even consequences, adoption of SLM technologies are below expectations and are still highly tied with incentives. Furthermore, the majority of farmers have limited knowledge on their legal rights and duties while using their lands.

In general, if appropriate actions are not taken to protect, restore and manage land resources sustainably, climate change adaptation and mitigation, biodiversity conservation, alleviating rural poverty and hunger, ensure long-term food security or building resilience to drought and water stress will not be achieved.

2. Poor adherence to policies and strategies

Though various natural resource management policies and strategies have been designed at the federal and regional level, they are not being properly translated into practices. The study revealed that what policies demand at the national and regional level and what is actually implemented at the grass root level is quite different. For instance, policy framework and watershed guideline emphasis on the importance of genuine community participation, gender equity and the need for recognition of the local knowledge and experience for effective land management practices. However, in reality they were not adequately implemented.

3. Poor design and lack of maintenance of SWC structures

Although the watershed management intervention follows principles of "ridge to valley" approach, there is no adequate auditing, monitoring, maintenance and management practices made for the previously installed conservation structures. More focus was typically given for construction of structures, and not for their maintenance. As the field observation confirms that most of the previous structures were wholly or partially destroyed in almost all parts of the watershed. Soil erosion aggravated by poorly sited & designed structures were not uncommon.

Although, in a very few cases, farmers take initiative to perform maintenance work on their private land, it was revealed that no maintenance was carried out on communal lands. Instead of maintaining damaged structure, every year, the campaign work focuses on building new structures by continuing from where it was stopped in the previous year. The principle: "*construction without maintenance did more harm than good*" have been overlooked or given only limited recognition". Efforts to link the physical and biological conservation activities with livelihood improvement activities were also extremely poor. In general, more attention has been given to the quantity rather than quality of the activities. This implies that the labor and time investment in achieving sustainable land management seems under question mark. Hence, the issue of land degradation and its subsequent impacts remains unabated.

4. Superficial community participation

In spite of strong rhetoric of community participation, this study revealed huge gap between its lip service and its actual implementation. The rhetoric on community participation pertaining to SLM is far away from realities. No effective and genuine community participation and mainstreaming participatory principles noticed in the watersheds. Land management plans and technologies always imposed from above (mainly from region and/ or zone). The participation of poor rural households in planning and decision-making processes was extremely low. Despite they offered free labor annually in SWC campaign work, a considerable number of community members do not have interest to fully participate due to lack of trust on the benefit obtained. Hence, sustainability of the management beyond free labor period is minimal. However, it should be recognized that there are a number of farmers who use their own initiative, technical skill and labor to practice SLM.

5. Knowledge gap and misconceptions regarding sustainable land management

A failure to understand and biases may result in wrong assumptions concerning the real problems, with the result that efforts to control land degradation are targeted in the wrong direction. In many situations the lack of understanding the root causes of land degradation has ended up with efforts being narrowly focused on addressing the visible symptoms rather than tackling the site-specific reasons for the occurrence of land degradation. Although there are promising and innovative technologies, approaches and supports decision-making and planning at the national level for sustainable land management, there are still many knowledge gaps and misconceptions regarding land management at the district, watershed and household levels, which must be addressed through training, evaluation and monitoring. Most of the activities are heavily biased toward labor-intensive conservation measures and there is a widely held perception among farmers that agricultural production is threatened mainly by recurrent drought.

Local administrative institutions need to be empowered. It was evident during the study that unqualified rural planners, weak rural planning skills, plans being prepared in rush, weak monitoring and evaluation approaches, insufficient participation of local communities in planning processes. The wrong belief that farmers know little or nothing about their own land management practices can lead to the imposition of unnecessary and often inappropriate solutions. The study highlights that farmers often have a good understanding of land degradation problems and what is required for sustainable land management. This confirms the general impression and misconception of farmers damaging their land/environment through ignorance.

More specifically, the study highlights that:

- The farmers well understood the problems of land degradation and even outline the causes and impacts. The challenge is lack of initiatives and commitment to the implementation of proposed solutions.
- Labor shortage was one among the main constraints for communities' participation, particularly at times of land preparation and harvest when the work has to be done in a very short time.
- Gender division of labor and male-biased attitudinal behaviors and practices are still prevalent among the community of the study area, which needs to be addressed.
- Many household heads participating in the survey opposed the practice of control grazing and prefer free grazing even for short periods
- In general, there are a tendency to adaptation to environmental degradation rather than adoption of sustainable land management practices
- Local institutions have found to be ineffective in enforcing land use policies and strategies

9.4 Recommendations for a Possible Way Forward

Cognizant of the interwoven and multifaceted nature of the problem prevailing in the study area and in the light of the above conclusions, the following general and specific recommendations have been proposed.

1. Limiting cropland expansion and diversification of livelihood options

Expansion of croplands / settlement areas should not be allowed at the expense of afro mountain ecosystems and other land use types. Since there is no idle land suitable to expand cropland in the watershed, adopting land use intensification using modern inputs is the only option to promote the production system of the watershed. It is also important to diversify livelihood options through planting of fruit trees, honey-bee production practices, commercial based sheep fattening and poultry production, which all of these local strategies do not require large space for investment.

In this regard, in addition to poultry farming, planting properly selected fruit trees has been encouraged more recently as an alternative income sources in the watershed. For example, in the *Wurch and Dega* agro ecologies, planting of Apple fruit trees and in *Weyna Dega* zone planting spice trees can increase income of the community instead of relying to sole cropping of grain crops. Since landholdings are scarce, planting of fruit trees should be encouraged along terraces and/or land boundaries.

Since there are no alternative livelihood options, youth out migration, mainly to urban areas are common from the watershed. This may not only cause some social problems in the destination areas to which emigration occurs, but also leaves problems behind. Hence, expansion of alternative livelihood opportunities and minimize migration of youths is recommended. Moreover, to minimize poverty situation, saving culture of the farmers must be improved. Any future cropland expansion should be limited to lands with low environmental opportunity costs

2. Focusing on the integrated natural resource management approach

Single measure intervention may not lead to most desired result. For the purpose of illustration, we can cite the soil erosion control mechanisms. While SWC is essential to minimize soil erosions, there is increasing recognition that it is no longer sufficient to fully stop the degradation of all watershed resources and ecosystem services. Moreover, as a conventional approach, terracing has contributed considerably to mitigating soil erosion of the sloping croplands. However, due to some constraints, it cannot be adopted in many places. Hence, biological measures such as nitrogen-fixing trees and shrubs need be integrated with bench terrace to solve problems of soil erosion and declining soil fertility. Although it is till in development stages, this technology has been under demonstration in the watershed, mainly in the SLM project sites.

Like the previous approaches, the current activity is still more oriented towards SWC activities. Hence, the most important lesson to be learned is avoiding the past mistakes and focusing on the integrated watershed resources management approaches instead of pursuing sector-oriented approaches. To utilize its full potential, the watershed resources must be managed as a system.

As highlighted in the Rio+20 Conference on land degradation neutral world, SLM practices would serve to alleviate rural poverty, improve livelihoods and restore degraded lands by addressing the nexus of food, energy and water in an integrated approach. In this regard, it is vital to adopt the overarching "sustainable land use for all and by all" principle as proposed in sustainable development goals for land degradation neutral world.

3. Promoting Community Engagement *and Managing Community Needs*

Community participation that goes beyond simple information sharing is essential at every stage of SLM activities, from problem identification to evaluation and monitoring, so that farmers have contributed their long-life experiences and develop sense of ownership and better understand the manner in which the system operates. *As highlighted in Principle 10 of the 1992 Rio Declaration on Environment and Development which asserts "Environmental issues are best handled with participation of all concerned citizens, at the relevant level".*

Though community participation is the passionate pursuit in the study area, over-centralization of decision-making has still been observed, and has been identified as major constraint to enhancing SLM practices. As noted above, there is huge gap between what is prescribed in the policy and what is practiced on the ground. It is, therefore, vital to rethink on the essence of community participation and approaches applied. For instance, in order to ensure meaningful responsibility and encourage community participation, time for free labor SWC works should be arranged according to farmer's convenience. So long as all the community members are not convinced and are not provided with equal opportunities and recognitions for their full participation, the greater goal of SLM will not be achieved.

It is equally important to try to better understand the attitude, indigenous knowledge and practices of rural communities related to implementation of SLM practices and pays attention to factors that influence community participations and adoption of SLM options. In fact, it takes an extraordinary effort to fully engage all the community members. To sum up, community participation should be more than just playing 'lip- service'. Hence, it is strongly recommended to **shift from "command *and control approach to thinking to genuine community engagement.*"**

To ensure SLM has significant impact for a community, it is important to address a community's most urgent needs. Therefore, it is important to rely upon well-respected community leaders and local organizations for an assessment of community needs and for greater background on the issues the community faces instead of simply relying on reports. This should be supplemented with academic research of this kind in the community. From these needs' assessments, community problems should become clearer, which in turn will allow the success of SLM activities.

4. Prioritized intervention of land degradation problem areas

Most of the current soil erosion risk areas are spatially confined in the steep slope northeastern parts of the watershed. It is believed that this part of the watershed is primarily characterized by shallow soils, steep slopes, and sparse vegetation covers. Moreover, unsustainable land management practices on sloping lands have accelerated the magnitude of soil erosion. During the field visit, this part of the watershed comparatively exhibited low level of SWC structures and removal of the vegetation cover. Therefore, it should be realized that these parts of the watershed need urgent and prioritized **intervention with appropriate SWC measures** by the local governments. Similarly, it is advisable to consider agro-ecological zones and local circumstances rather than think of a single best approach if they are to have a real impact on both livelihoods and environmental conservations.

Moreover, adopting "**dual-pronged approach**" is important to counterbalances the expected loss of productive land with the recovery of degraded areas. This approach involves measures to avoid or reduce degradation of land, combined with measures to reverse past degradation in order to achieve both SLM and sustainable development, as highlighted in the sustainable development goals target 15.3

5. Improving the existing extension services and bridging capacity gaps

The SLM Programme demands attractive institutional working environments, qualified technical experts as well as development agents to properly support farmers in the field. In this regard, the extension services in the watershed needs to be critically revisited and shaped to make it more responsive and efficient to address the problems associated with land degradation. Iterative training for field staff on policy frameworks and implementation guidelines is important to substantially improve the efficiency of the system. The author suggests that development agents should live and work among and near farmers and they should be familiar with farmer's practice, social structure, problems and aspirations instead of following the old-fashioned practice of telling farmers what to do. Recognizing the value of the existing cultural practices such as local bylaws, belief systems by the DAs can increase farmers' trust and responsiveness.

On the other side, filling capacity gaps (of technology developers, experts and development Agents) and solving their problems is important pathway to catalyze success of SLM practices. Meaningful progress towards SLM practice requires availability of theoretical and technical knowledge along with lessons learned from previous experience, thus it is imperative to fill capacity gaps to effectively and sustainably achieve the required goals.

6. Scaling-up SLM success stories in the watershed

It has been mentioned that there are pockets of successful SLM practices in different kebeles (within or out of the watershed) of the district. However, there is no attempt and clear scaling-up mechanism to scale-up the success. SLM intervention programme needs to be farm-and farmer-specific, that is, it should meet the peculiar needs of various categories of farmers and agro ecologies in order to achieve sustainable productive livelihoods. SLM practices need to be attached to income both at household and community levels. Since, most farmers hold "**a wait-and-see attitude',** it is advisable to show concrete evidence that other farmers had been able to benefit from application opportunities presented by the SLM practices. This means demonstration of the opportunities that SLM can offer is essential to promote SLM practices. In this regard, strengthening **farmer field school approach** plays productive role in sustainable land management activities.

7. Improve cost and benefit sharing mechanisms

There are empirical evidences that available natural resources are mostly benefiting those who reside near the rehabilitated areas. This holds true especially for exclosures. For instance, those who live near the area let their animals to graze while grazing is not allowed and cut and carry grass for livestock feed and construction without permission. Whereas those who live far away from resources do not get these benefit. Therefore, cost and benefit-sharing is critical to sustainably manage these resources. To this end, we recommend that unequivocal rules and guidelines about cost and benefit-sharing arrangements regarding to natural resources of enclosures should be existed and consistently implemented.

8. Promoting development of infrastructures

Infrastructures in its various forms are important because they contribute to agricultural sectors, as it is the key determinant of the cost of accessing input and output markets. It is apparent that the government of Ethiopia implemented encouraging reforms in the last decades, with a major one being improving access in telephone services, education & health sectors. However, improvement in other key sectors such as access to energy, irrigation infrastructure and roads are still very limited and not keeping pace with the need particularly in remote areas like Gedalas Watershed. For instance, while recent progress has been made toward introducing alternative energy sources (ex. solar panel energy for night time lighting), barriers remain to expand these vital energy sources and hence, the community still mainly depends on biomass energy which is one of the main factors for vegetation degradation in the study area.

Similarly, poor road network (frequently damaged roads and absence of bridges on streams which cut farmers off from markets in every rainy seasons) of the watershed imposes huge challenges to supply of SLM enhancing inputs. For example, lack of quality road network and in accessibility of the watershed has led to significant delays and supply of small quantity of fertilizers into the area. This not only has translated to high costs for fertilizers but also most farmers do not get access to it at appealing rates.

Moreover, there are huge areas conducive for irrigation purpose. However, as the report from Woreda agriculture office revealed irrigation infrastructure is very limited with less than 7% of currently used agricultural land being irrigated in the district. Hence, it is advisable to tap the remaining irrigation potential of the district in general and the study watershed in particular.

Last but not least, remote sensing technologies, such as high-resolution satellite images, sentinel and Google earth data, along with historical/ existing ground-based data and maps, provide reliable information necessary to monitor the state and trends of land degradation/rehabilitation progress at all spatial scales. These tools are also essential for prioritizing land management interventions and supporting efforts towards reversing land degradation trends. It is therefore imperative to strengthen capacities of institutions to access and use these vital information sources.

Suggestions for further research

Based on the findings of this study, the following key areas were suggested for further research.

1. The RUSLE model used in this study do not directly account for gully erosion. Hence, for a more accurate soil loss estimation and erosion risk data, further investigation and onsite measurement of gullies should be carried out in the watershed.
2. Institutions have played a pivotal role in influencing the actions of farmers. Hence, further research is needed to study on how:
    - could local institutions and support systems be transformed to convey better services to farmers to enhance farm level SLM activities
    - the existing SLM approaches and implementation strategies be modified based on on-ground realities to meet current needs and solve challenges of the community
    - to enhance real participation of farmers in SLM practices given the socioeconomic and institutional constraints
3. The issue of incentives for community participation remains a debating issue with strongly held positions for and against; it would be helpful to further explore in detail the value and problems of incentives for enhancing public involvement in SLM activities.
4. Further study on land suitability evaluation is also important to identify other alternative optimum land uses options in the watershed.

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APPENDICES

Appendix 1: Data collection tools used in the research

A. Questionnaire for farming households

Household survey questionnaire (form no. ---------)

Geographic information

- ☞ Kebele …………………. Village/local name ……………. Agro-Ecology…………….
- ☞ Date of interview …………… Name of interviewer…………………..

1. Household demographic information

1.1. Name of the acting head of the household -- household head's Id:---

1.2. Sex: 1. Male ------------- 2. Female-------

1.3. Age in years -----------

1.4. Level of education

1. Unable to read & write -------
2. Adult literacy----
3. Grade 1-4 -------
4. Grade 5-8 ---------
5. Grade 9-10---------
6. Grade 12 and above -------

1.5. Marital status:

1. Single ---------
2. Married ---------
3. Divorced-------
4. Widowed---------
5. Others-----------

1.6. Size of your household, including yourself, by age group and gender

Age in years	**Male**	**Female**	**Total**
1. Less than 15			
2. 15-64			
3. Above 65			
Total			

1.7. How long have you been farming? ------------years

2. HOUSEHOLDS LABOUR

2.1. Do you feel you have enough time to properly manage your farm land? 1. Yes ---------2. No -------

2.2. What are the numbers of household members working on your land on full time basis? -------------

2.3. Did you use labor other than member of your household for land management activities? (**If "No" skip to Q.2.5**.) 1. Yes---------2. No-----------------

2.4. If yes, how do you get these labors? ---

2.5. Do you or any of your household members have engaged in other income generating activities? (**If "No" skip to Q.3.1**.) 1. Yes------------------------- 2. No------------------------

2.6. If yes, what is/are these activities? (Multiple responses are possible)

1. Pity trade-----------------
2. Craft making -----------
3. Daily work---------
4. Selling of Beers--------------
5. Other, /specify, if any/------

3. DETAILS OF LAND HOLDING

3.1. Land ownership (lands operated/ owned by the households) in hectare/Timad?

Type of land ownership	Approximate size of each Parcel of land in (in hectare/Timad)		
	During Imperial regime (before 1974)	During Derg regime (1974-1991)	After 1991
A. Private 1. Homestead			
2. Cropland			
3. Irrigated land			
4. Grazing land			
B. Communal grazing land			

3.2. Are all your farmlands in one unit/place? 1. Yes--------- 2. No------------
3.3. If not, totally, how many fragmented farmlands (parcels) do you have? ---------------
3.4. Does the fragmentation of your plots have any adverse effect on your land management effort? (If "No" skip to Q.3.6.) 1. Yes --------- 2. No -----------
3.5. If yes, what are these effects? ____________
3.6. How many minutes it takes to travel on foot from your home to the most distant farmlands? --------------------
3.7. Indicate the relative topographic position of your farmlands

Position	Plot Number (1,2,3,4,5--)	Slope category 1. Gentle 2. Moderate 3. Steep 4. Very steep	suitability for ploughing 1. Highly suitable 2. Moderately suitable 3. Not suitable	Name of crops grown (***List three in rank order***)
1. Hillside				
2. Valley				
3. Top				

3.8. How do you acquire your plot of lands?
1. Inherited from parents---------- 2. Was allocated by the government------------------- 3. Others (explain) --
3.9. is your current land holding sufficient to support your family? 1.Yes------------- 2. No----------------

4. **COMMUNITIES' PERCEPTION AND EXPERIENCE ON LAND DEGRADATION**

4.1. Do you know about land degradation? 1. Yes-----------2. No-----------------
4.2. What is your view on the general trend in the status the following natural resources over your life experience? [*Mark in the appropriate box*]

Natural Resources	Stable	Decreasing	Increasing	If reducing, list major causes for its decline	Major Consequences
1. Natural forest/ vegetation cover					
2. Plant species diversity					
3. Soil fertility/productivity					
4. Water resource availability/distribution					
5. Wildlife diversity/availability					

4.3. Have you perceived occurrence of soil erosion on your farmland/s or localities? Yes-----------No------
4.4. If yes, what are the indicators of soil erosion over time on your farmlands/locality?

4.5. What do you think are the causes of soil erosion on your farmland/s/locality? ------------**---------------------**
-- 4.6. What is the extent of soil erosion on your farmlands?
1. Severe----------- 3. Moderate-------- 3. Minor----------4. Difficult to estimate-----------------
4.7. The rate of soil erosion over your life experience
1. Increasing--------- 2. Remains the same ---------- 3. Decreasing---------
4.8. Do you think that soil erosion affects land productivity? (**If "No" skip to Q.4.10**.)
1. Yes --------- 2. No ----------
4.9. If yes, how does it affect land productivity? ....
4.10 From your experience, which type of crops preferably grown on degraded lands? --------------------

4.11. Which crop types exhaust soil fertility status (*List three in rank order)* ---------------------------------------
4.12. Which crop types improve soil fertility status (*List three in rank order)* ---------------------------------------
4.13. What Measures do take to enhance the declining fertility of the farm land?

1. Crop rotation ------------
2. Shift to other land------------
3. Using manure----------------
4. Expand the farm land-----------
5. Use fertilizer---------------
6. Change land use type---------
7. Fallowing---------------
8. Others------------

6. **COMMUNITIES' EFFORT TO GROW TREES**

6.1. Do you have own planted trees/wood lots on your plot? (**If "No" skip to Q.6.3**.) 1. Yes-------- 2. No----

6.2. If yes, would you mention Tree Type (species) and purpose/most important use of these trees?

Tree Type (local name)	Purpose
1.	
2.	
3.	

6.3. If your answer is no, for question 6.1, why?

1. Lack of land -------
2. Lack of labor ---------
3. Lack of seedling --------
4. Feeling of tenure insecurity ---
5. Others, specify----------

7. HOUSEHOLD ENERGY

7.1. What are your main sources of fuel for cooking & heating? (put in rank from first to last)

1. Firewood--------
2. Charcoal----------
3. Cow dung (dung-cakes) --------
4. Crop residue-----------
5. Kerosene---------
6. Biogas------------
7. Others, /specify, if any/---------------

7.2. From where do you collect fuel wood?

1. private land plantation---------
2. community plantation---------
3. community shrub lands------------
4. If any Others, /specify /---------------

7.3. Do you own fuel saving stove? (**If "No" skip to Q.8.1**.)
1. Yes------------ 2. No--------

7.4. If yes to question 7.3, where do you get?

1. Support from NGO------------
2. Support from the Government--------
3. Buying from market --------------
4. Make it myself---------------
5. Others, /specify, if any/----------------

7.5. If you uses fuel saving stoves what benefit do you get from it? -------------

8. COMMUNITIES' PERCEPTIONS ON LOCAL CLIMATE CHANGE AND VARIABILITY

8.1. Have you ever heard of the term climate change? (**If "No" skip to Q.8.3**.)

1. Yes------------ 2. No-------------------

8.2. If yes, what does it mean for you? ---

8.3. Have you noticed any significant changes in weather patterns over your experience in your locality? (**If "No" skip to Q.9.1**.) 1. No----------- 2. yes-------------

8.4. If yes, what climate change related events have you observed in your locality?

Elements of climate	Local perceptions			
	Increasing	Variable	Decreasing	No change
1. Trends of rain fall				
2. Erratic dry spells during the rainy season				
3. Heavy rainfall events (intensities and amount)				
4. Incidence of drought				
5. Trends of temperatures				
6. Changes in flowering and fruiting time of crops				
7. Incidence of diseases in crops				
8. Behavioral changes in livestock				

8.5. For the changes mentioned above, what are some of their impacts on your household, the environment etc---

9. ADAPTATION TO CLIMATE CHANGE AND VARIABILITY

9.1. How could you adapt to adverse drought conditions?

Options	**Yes**	**No**
1. planting drought resistant crops		
2. Depend on Relief aid		
3. Rain water harvesting		
4. Use of irrigation		
5. Changing diet		
6. Selling of live stocks		
7. Out migration		
8. Others, specify		

9.2. Which groups of individuals in the household suffers the most in case of food shortage due to drought conditions?

1. Children----------
2. Women----------
3. Men--------------
4. Elderly group--------
5. Youth--------------
6. All suffers equally----

9.3. Which domestic animals are most vulnerable to adverse climatic conditions? -------------------------------

SUSTAINABLE LAND MANAGEMENT ISSUES

10. LOCAL COMMUNITIES' AWARENESS ABOUT SOIL FERTILITY MANAGEMENT OPTIONS

10.1. Do you think soil fertility of your farm lands changed through time? 1. Yes-------- 2. No------------

10.2. If yes, why has it changed? ---------------------------------

10.3 To what level do you agree with each of the following soil fertility management options? Please indicate your answer using the following 5-point scale where:

1 = strongly disagree (SD) 2 = disagree (D) 3 = neutral or undecided (N) 4 = agree (A) 5 = strongly agree (SA)

STATEMENTS	SD	D	N	A	SA
1. Crop rotation improves soil fertility					
2. Use of chemical fertilizer improves land productivity					
3. Soil and water conservation structures improves soil fertility					
4. Plowing lands again and again improves Soil fertility and crop productivity					
5. It is better to use cow dung and crop residue as a manure than as fuel for cooking					
6. Free grazing of communal land by animals should be stopped					
7. I know how to prepared and apply compost to maintain soil fertility					
8. Plowing steep slope have no negative effect on soil fertility					
9. Free grazing on cropland has no effect on soil fertility status					

11. LOCAL COMMUNITIES' ATTITUDE TOWARDS AREA CLOSURE AS STRATEGY OF DEGRADED LAND REHABILITATION AND MANAGEMENT OPTIONS

11.1. To what extent do you agree with each of the following statements related to area closure? Please indicate your answer using the following 5-point scale where:

1 = strongly disagree (SD); 2 = disagree (D); 3 = neutral or undecided (N); 4 = agree (A); 5 = strongly agree (SA)

Importance	SD	D	N	A	SA
I believe that SLM practices greatly improve productive capacity of lands					
I believe that SLM practices prevents land degradation					
I believe that degraded lands should be closed from human and livestock interference for effective rehabilitation					
I think Overgrazing should be stopped as it exacerbates land degradation problems					
I think closed areas should be protected and managed by the local community					
It is better to use cow dung and crop residue as a manure than as fuel for cooking					
I believe that use of chemical fertilizers on my plots is important to improve land productivity					
I believe that preventing my plot from soil erosion and associated land degradation is my responsibility					

12. Community awareness and attitude towards swc practices

12.1. Are there soil and water conservation activities on your farmlands/locality? 1. Yes-------- 2. No----------

12.2. If yes, are soil and water conservation measures implemented on your locality demand driven?

1. Yes-------- 2. No ------------

12.3. How do you evaluate SWC structures implemented on your farmlands/locality in terms of the criteria listed below (use the following Scale: **1= very good 2= fair 3= poor?**

Type of conservation measures/ management practices	Evaluation Criteria								
	effectiveness to control soil erosion	Potential in improving productivity	Ability to retain soil moisture	Alignment with indigenous	Simplicity to design and implement	Simplicity to Maintenance	Labor & material requirements	Suitability for free grazing	Local availability, affordability
1. **Physical SWC practices**									
Fanya juu bunds									
Stone bunds									
Stone faced soil bunds									
Soil bunds									
Diversion ditches									
Check dams									
Cut off drain									
Bench terrace									
Waterway									
Hillside terracing									
2. Biological SWC practices									
Compost									
mulching									
Fallowing									
Manuring									
Planting trees									
Agro forestry									
Others such as-----------------									

13. Local communities' attitude towards contemporary community-based watershed management activities

A. Conformity to watershed management principles

13.1. How do you evaluate the current community-based watershed management activities based on the criteria below?

Evaluation criteria	**Yes**	**No**
1. Watershed management interventions are based on local problems		
2. Watershed management interventions progressively proceeds from upper part of the micro-watershed to lower part of the watershed		
3. The overall watershed management plans are prepared by the community themselves with technical advice from experts		
4. Problems identification and prioritization for possible technical interventions are entirely based on participatory community consensus		

5.	Selection of technologies is in accordance with their suitability to local environments (biophysical & socio-cultural setup of the watersheds)		
6.	Individuals' participation is ensured by providing tangible economic benefits		
7.	The current watershed management activities are cost effective and environmentally friendly		
8.	Local knowledge is combined with scientific ones for the watershed management activities		
9.	Capacity building to local farmers are being given to promote and sustain effective watershed management activities		
10.	All stakeholders (such as youth, women, men and landless people etc) are involved in the watershed management activities		
11.	There is equitable benefit sharing for common resources (There is equity in both costs and benefits)		
12.	There is continuous monitoring and participatory evaluation of the overall performance of watershed management by the community		
13.	Management of watersheds will continuous after the cessation of the program		

B. Level of community participation and approaches for moblization

No.	A. Level of participation/Approaches	Yes	No
1	Participated in watershed management consultative and consensus-built meetings		
2	Participated in identification of priority areas for watershed management activities		
3	Participated in watershed management decision making activities		
4	Participated in developing plan of work		
5	Participated in implementation of watershed management activities		
6	Participated in watershed management execution activities		
7	Participated in monitoring the progress watershed management activities		
8	Participated in evaluation of watershed management activities for reconsideration		
B. Type of participation			
1	My participation is Voluntary		
2	My participation is Forced		

C. Access to information and training

13.2. Do you have radio? (**If "No" skip to Q.13.5**) 1. Yes----2. No---------------

13.3. If your response is yes, have you heard about land management issues in its program?
Yes---------No--------------

13.4. If your response is yes, would you list some of them? -----------------

13.5. Have you got training and technical support with regard to land management issues? (**If No, skip to Q. 13.7**)
1. Yes---------2. No--------------

13.6. If yes, indicate the training area that you participated?

Training content	Duration (hours, Days, etc)	Outcome

13.7. If your response for question No.13.5. is yes, from whom did you get the support?

1. Development Agent
2. Wereda soil and water conservation expert
3. from local NGO's
4. Others, specify---------

13.8. Are you satisfied with the technical support and advice provided?
1. Yes---------2. No--------------

14. Communities' perceptions on the impact of contemporary watershed management

14.1. To what extent do you agree with each of the following statements related to the impacts of contemporary watershed management efforts? Please indicate your answer using the following 5-point scale where:

1 = strongly disagree (SD); 2 = disagree (D); 3 = neutral or undecided (N); 4 = agree (A); 5 = strongly agree (SA)

No.	Statement	SD	D	N	A	SA
1. BIOPHYSICAL IMPACTS						
1	Availability of Surface waters for humans and animals drinking improves					
2	Lands productivity increases					
3	Fuel wood availability improves					
4	Over all vegetation cover of the area improves					
5	Soil fertility improves					
6	Microclimate of the watershed is improving					
7	Water and soil losses have been reduced significantly					
8	Unproductive & degraded wastelands have been turned in to productive lands					
9	Flood/runoff damage reduces					
2. FOOD SECURITY AND LIVELIHOOD IMPACTS						
1	Crop production and productivity increases					
2	Livestock productivity increases					
3	My household assets improve (E.g housing and others)					
4	My productive assets improve (farm tools, oxen,					
4	My household saving improves					
5	Availability of livestock feeds improves					
6	My total annual income covers my household expenditure					
7	Overall household's food insecurity and poverty situations declines					
8	My household nutritional diversity increases					
9	My ability to cover school expenses to my children improves					
10	Over all livelihood options improved					

15. LIVELIHOOD ISSUES

15.1. CROP PRODUCTION

Type of crops produced	Local name	Trends of production		
		Increasing	No change	Decreasing
Cereals				
pulses				
Oil seeds				

Others				

15.2. Is your food production adequate to cover your families' annual food consumption requirement? Yes ---2. No ----

16. LIVESTOCK PRODUCTION AND MANAGEMENT

16.1. Do you rear livestock? 1. Yes ----------- 2. No. ----------------

16.2. If yes, please fill the number of livestock owned, source of fodder and type of grazing used in the table below

Livestock type	Total number	Source of fodder 1.*Grazing on common pasture* *2. Grazed on own pasture* *3. Crop residue* *4. others*	Type of grazing 1. *Free grazing* *2. tethering*
Cattle			
Horses			
Mules			
Donkeys			
Goats			
Sheep			

16.3. How do you see the trend of livestock both in number and type for the last 20 years?

Increasing 2. Decreasing 3. No change 4. Difficult to estimate

16.4. Do you think the grazing land on your farm/area is degraded? Yes--------------2. No----------------

16.5 If yes, why do you think this has happened? --

16.6. What problems or constraints do you face in management of grazing areas? ----------------------------

17. OVER ALL COMMUNITY PERCEPTIONS ON LOCAL LEVEL DEVELOPMENT ISSUES

17.1. How do you rate the following services (Support) provided at village Level in your community?

Service (Support)	How do you rate the Services			
	1.Excellent	2. Good	4. Average	remarks
Hold community meetings to raise awareness on SLM issues				
Work with local communities, consult & integrate local knowledge to identify and prioritize for SLM intervention				
Provision of reasonable incentives for promotion of SLM practices				
Support on formulation & Clarity of community bye-laws				
Technical support and advice on SLM programs				
Set up demonstration plots to promote SLM practices				
Assess capacity gaps and provide consultation, facilitate training, experience-sharing visits and capacity building as deemed necessary				
Training on existing government policy, legislation, proclamations and enforcing procedures to the community				
Access to credit				
Support for livestock disease prevention				

support for preventing crop pests				
Access to improved livestock				
Access for roads				
Access for schools				
Support for compost preparation				
Others, /specify, if any/				

18. OVER ALL CONSTRAINTS AND SUGGESTIONS

18.1. Indicate the major Problems of the area and your suggestions for future improvements/further strengthening

No.	Problems	Suggestions
1		
2		
3		

B. INTERVIEW GUIDE QUESTIONS FOR KEY INFORMANTS (GOVERNMENT AGENCIES)

Personal Information

- Name --------------------------------- Date of interview ....
- Educational Level-------------------------
- Current position---------------------------
- Total Experience-------------------------------------
- For how long have you been working/living here in your current position------------years
- Major Responsibilities------------------------------

Land degradation, Sustainable Land management / degraded land rehabilitation /restoration efforts

1. What is your experience on the historical changes of the state of the local environment in terms of land use, vegetative cover, plant and wildlife composition (natural biodiversity), water resources distribution and quality, local climate and soil fertility/productivity over your experience? If any changes, what do you think are the causes of the change?
2. Have you experienced the problems of soil erosion/land degradation in this area? What is the magnitude of the problem?
3. From experience, what are the main causes for soil erosion/land degradation in this area?
4. Are there any sustainable land management efforts to prevent soil erosion/land degradation in this locality? If any, can you mention the land management practices in place in the locality? Why are these technologies chosen in this area? Are there any problems related to implementation of these practices? If any, can you mention the problems associated with implementation of these technologies?
5. What strategies do you apply to overcome these challenges?
6. How do you reliably assess and monitor the existence of soil erosion /land degradation risks in the locality so as to recommend appropriate management practices?
7. Do you think that the current sustainable land /watershed management programs address these problems?
8. How the watershed priorities are identified and what steps / processes are followed during the planning?
9. Who identifies the integrated watershed and landscape management activities at the community level?
10. Are there any enabling environment provided by the Government and/or NGO sectors including institutional support e.g. providing training, technical support, access to inputs, incentives etc)?
11. How often do you visit farmer's plot?

12. Do you have time schedule to follow up the activity of the local farmer?
13. What is/are your role/s in the watershed priority areas identification?
14. How do you involve and mobilize local communities in implementation of watershed management activities?
15. Do all stakeholders participate in different stages of watershed development programme?
16. How do you evaluate local people's participation and commitment to sustainable land management activities?
17. Which group of people is better in terms of participation in watershed management activities? Is it male or female? The young farmers or old farmers?
18. How do you strengthen the capacities of local communities for easily acceptance and adoption of the sustainable land management activities?
19. Are there any kinds of regulations & by-laws to participate local communities in sustainable land management practices in the Woreda? If any, can you mention them? How are these regulations enforced?
20. Are there any advisory and extension services provided to the local communities to raise awareness and manage with sustainable land management options? If any, what kind of advisory and extension services provided to the local communities? How often?
21. Is there incentives being given to local communities for easy adoption of sustainable land management technologies? If any, what kind of incentives?
22. Are there clear system concerning ownership control and utilization of afforested areas and closed hillsides?
23. What changes do you observe in the localities after the beginning of the implementation of sustainable land /watershed management programs?
24. How do you evaluate the sustainability of watershed management activities in the locality?
25. Based on lessons learned, what success did you experiences in the process of sustainable land management programs implemented so far?

OTHER DISCUSSION POINTS

- Local watershed management guidelines and its content
- Institutions, NGO's and projects involved in the promotion of SLM related innovations & their coordination and alignment of efforts
- Mechanism for coordinating all agricultural and rural development efforts
- Consultations with diverse social groups and landscape position
- Integrated solutions to watershed problems
- Incorporating local perspectives
- Availability & supply of tools
- Watershed committee members & structures
    - Selection/election criteria
    - Duties and responsibilities
- Assessment of success and failure
- Compliant treatment methods/approaches

C. INTERVIEW GUIDE QUESTIONS FOR KEY INFORMANTS (local community)

Personal Information

- Name --------------------------------- Date of interview …………..
- Kebele---------------village-------------------------
- Agro ecology----------------------------
- Farming Experience-------------------------------(Years)

1. What is your life experience on the historical changes/trends of the state of the local environment/ land in your locality in terms of?
    A. Land use change
    B. Vegetative cover /plant composition (what plant species become scarce? Why?)
    C. Wildlife composition (natural biodiversity)
    D. Soil fertility/ productive capacity
    E. Water resources distribution and quality
    F. Local climate
2. If any changes, what do you think/are the causes of the change?
3. Are there erosion /land degradation problems in your locality?
4. How do you know the existence soil erosion /land degradation in your locality?
5. Do you think that the current sustainable land /watershed management programs address these problems?
6. What changes do you observe in your localities after the beginning of the implementation of sustainable land /watershed management programs?
7. Are there any enabling environment provided by the Government and/or NGO sectors including institutional support e.g. providing training, technical support, access to inputs, incentives etc)?
8. How do you evaluate local communities' awareness/ participation from the following point of view?
    - Consultations with diverse social groups (E.g. By gender, age, wealth, and landscape position)
    - Participation to identify key watershed problems
    - Participation in planning & decision making
    - Participation in technology selection / selection of watershed intervention priorities
    - Participation in the implementation of sustainable land management technologies
    - willingness in community mobilization activities
    - Community participation in by-law formulation & revision
    - Participation in effectiveness of the byelaws
    - Community awareness of legal statutes
    - Incorporating local perspectives
    - Willingness to contribute labor voluntarily
9. How do you evaluate the adoption/adaptation of SLM technologies by the local communities'?
10. Are there incentives provided to those who participated in sustainable land management programs? If yes, what are these incentives?
11. Which incentives seem to work best? Which do not appear to be effective?
12. If this incentive stops, would you think they will be willing to participate in SLM?
13. How do you see the impacts of SLM on the environment and livelihood of each households and the community at large?
14. Have you obtained support and advice from the Wereda and development agents or any other concerned institutions related degraded land rehabilitation techniques?
15. How do you evaluate the advice and technical support provided from development agents?

16. What are the major bottlenecks, in your opinion, in implementing the watershed management activities in your Keble?
17. Based on your opinion, what should be done to promote farmer's participation and acceptance in sustainable land management activities?

CLIMATE CHANGE AND VARIABILITY

1. Have you ever heard of the term climate change?
2. How would you describe the current temperature and rain fall condition of this area as compared to over the past 20 years? What indicators are there?
3. Are there any method of cultural interpretation on climate change and variability by the community?
4. Would you consider this area more vulnerable to the devastating effects of drought and famine today than in the past?
5. What do you think are the reasons?
6. What possible solutions do you suggest to cope up with the problem?

D. **OBSERVATION & MEASUREMENT CHECKLIST AT WATERSHED LEVEL**

Description of the sub watershed

- Area ------------
- total Population------------
- Local economy------------------

OBSERVATION & GROUND SURVEY CHECKLIST (SAMPLE)	
1. Present type Land use/ Land cover type	
2. Topography (elevation)	
3. Topographic setting of plots, ploughing condition, pattern of plots etc	
4. Mean Slope & Slope length of sample arable field	
5. Drainage pattern of the watershed	
6. Farming system (the major crops grown, livestock type)	
7. Vegetation types (Tree- Indigenous & Exotic) and associated biodiversity	
8. Conservation structure (types & status)	
9. Livestock grazing area & grazing systems	
10. Soil (depth, color)	
11. Surface water distribution & Source of potable water	
12. Source of firewood	
14. Settlement Pattern & distributions	
13. Application of fertilizers (type)	

ON-FARM OBSERVATION CHECKLIST ON SOIL EROSION VISUAL INDICATORS ((TICK IF EVIDENCED)

Sample plots	Visual indicators	Visible	Not visible
1	Evidence of rill erosion		
2	Evidence of sheet erosion		
3	Evidence of gullies		
4	Accumulation of soils around clumps of vegetation and other barriers		
5	Deposit of soils on gentle slopes		
6	Exposed roots or parent materials		
7	Muddy water/mudflow during and shortly after rainfalls		

8	Sedimentation on the banks of streams		
9	Increased stoniness of the farm		
10	Availability of abandoned lands due to degradation		

ON-FARM OBSERVATION CHECKLIST ON SOIL FERTILITY MANAGEMENT INDICATORS ((TICK IF EVIDENCED)

Sample plots	**Visual indicators**	**Yes**	**No**
1	Application of Commercial fertilizers (asking)		
2	Crop residue after harvest		
3	Evidence of mulching		
4	Evidence of intercropping		
5	Evidence of mixed cropping		
6	Crop rotation (asking)		
7	Evidence of use of animal manure		
8	Evidence of use of green Manure		
9	Evidence of fallow system		
10	Application of lime		
11	Use of composite		
12	Others		

ON-FARM OBSERVATION CHECKLIST OF SOIL AND WATER CONSERVATION STRUCTURES ((TICK IF EVIDENCED)

Farm plot	On farm **conservation structures**	YES	NO
1	There is no conservation structures at all		
2	Whole farm is treated with conservation structures		
3	Only small portion of land is treated with conservation structures		
4	conservation structures are completely destroyed		
5	conservation structures are available but partially destroyed		
6	conservation structures are well stabilized		

D. Soil sampling points, Geo-references & other parameters

- Sub Watershed----------
- Site ------------

Sample No	Topographic position	Present Land use/ Land cover type	Agro Ecology	Altitude (elevation)	GPS (Lat/Long)	Slope (%)	Soil erosion control measures

A. Documents Review

- **List of some policies, proclamations and strategy documents consulted**
    - Agriculture and Rural Development Policy
    - Growth and Transformation Plan (GTP I & II)
    - Environmental Policy of Ethiopia
    - Population policy of Ethiopia
    - Water resource management policy of Ethiopia
    - Ethiopia's Food Security Strategy
    - Ethiopia's Agricultural Sector Policy and Investment Framework
    - A Plan for Accelerated and Sustained Development to End Poverty (PASDEP)
    - Climate- Resilient Green Economy strategy, FDRE, 2011
    - Other documents (e.g. national and regional proclamations, implementation guidelines and statistical reports**)**

Appendix 3 List of District level Key informants contacted

S/N	**Name**	**Responsibility**	**Departments/Sectors**
1	Mohammed Taddese	Team Leader	Livestock resources development
2	Fozia Yimer	expert	
3	Moges Molla	expert	
4	Mohammed Belay	Team Leader	Water resources & Energy Development
5	Tefera Belay	Team Leader	Natural Resources Management
6	Mesfin Melaku		
7	Ale Aseffa	expert	
8	Shimelis Yimam	Soil conservation expert	
9	Demiss Yimer	Unit Coordinator	Agricultural Extension
10	Teka Tesfaye	Team Leader	Food Security
11	Anwar Seid	expert	
12	Mohammed Melaku	Team Leader	Land Administration and use
13	Solomon Gezahgen	expert	
14	Birhanu Yimam	expert	
15	Yimer Walelign	Development Agent	Sengolla
16	Mohammed Alebachew	Development Agent	Kabohager
17	Shibrie Hassen	Development Agent	Wertej
18	Bezabih Shume	Development Agent	Gaya
19	Gashaw Ayalew	Development Agent	Haroghie
20	Mulugeta Berhie	Team Leader	Agricultural Input supply

Appendix 3 Soil Laboratory Test Results

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CDSWC

Ethiopian Construction Design &
Supervision Works Corporation
Water & Energy Design &
Supervision Works Sector

Soil Fertility Section — የአፈር ለምነት ክፍል

Tel. 251 - 116 - 61 45 01 / 251 - 116 - 61 01 05 — Fax. 251 - 116 - 61 53 71/61 08 98 — e-mail w.w.d.s.e@ethionet.et — P.O.Box 2561 — Addis Ababa, Ethiopia

Client:- Asnake Yimam

upper grass / upper crop / middle crop / grazing / lower crop

Laboratory Number	645/09	646/09	647/09	648/09	649/09	Test Method
PROFILE CODE	Sengola Yegtosh meret	Delgo-Crosure Land	Cherer-grass Land	Delgo-Crop Land	Delgo-Irrigated land Composite	
DEPTH (CM)	0-20	0-20	0-20	0-20	0-20	
Received Date	28/12/16	28/12/16	28/12/16	28/12/16	28/12/16	
Sand (%)	23.12	25.12	27.63	27.82	22.31	Hydrometer
Clay (%)	45.48	45.58	47.52	49.56	40.44	
Silt (%)	31.40	29.30	24.84	22.62	37.25	
Texture Class	clay	clay	clay	clay	clay	
P^H-H_2O (1:2.5)	6.54	7.15	6.92	6.84	7.52	Probe method
EC(ms/cm) (1:2.5)	0.13	0.13	0.09	0.11	0.17	
Exch.Na(meq/100gm of soil)	1.18	0.95	1.06	1.25	1.31	Ammonium Acetate & Instrumental
Exch.K(meq/100 gm of soil))	0.32	0.82	0.42	0.79	1.63	
Exch.Ca(meq/100 gm of soil)	48.65	51.77	45.11	45.01	43.69	
Exch.Mg(meq/100 gm of soil)	15.07	13.81	12.03	15.00	13.57	
CEC(meq/100 gm of soil)	81.90	76.44	65.85	64.77	64.55	
Sum of Cations (meq/100gm of soil	65.22	67.34	58.62	62.05	60.20	
Organic Carbon(%)	2.64	1.44	0.70	1.18	1.90	Walklay Black
Nitrogen (%)	0.26	0.17	0.09	0.17	0.27	Kjeldahl digestion
Available P(mg P_2O_5/kg soil)	47.94	108.22	90.90	122.82	169.07	Olsen
Available K(mgK_2O/kg soil)	117.39	396.40	150.79	371.29	642.08	Ammonium Acetate
Exchangeable Sodium %(ESP)	1.44	1.24	1.60	1.93	2.03	
Available Sulphur	0.55	0.25	0.07	0.08	0.25	KH_2PO_4 Extraction
Bulk Density(gm/cm^3)	1.11	1.87	1.94	1.88	2.00	Gravimetric
Particle Density (g/cm^3)	2.64	2.60	2.67	2.63	2.61	Volumetric

Remark:

Processed by ______ Date 18/01/17

Checked by ______ Date 18/01/17

Approved By ______ Date 18/01/17

Ethiopian Construction Design & Supervision Works Corporation, Water & Energy Design & Supervision Works Sector, Laboratory Service

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Ethiopian Construction Design &
Supervision Works Corporation
Water & Energy Design &
Supervision Works Sector

Soil Fertility Section — የአፈር ለምነት ክፍል

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Ethiopia

Client:- Asnake Yimam

b upper crop — lower closure — upper closure — lower grass — middle crop

Laboratory Number	650/09	651/09	652/09	653/09	654/09	Test Method
PROFILE CODE	Gaya-Crop Land	Waboshina-Crop Land	Sengola - Closure Land	Delgo-Grazing Land	Sengola-Croup Land	
DEPTH (CM)	0-20	0-20	0-20	0-20	0-20	
Received Date	28/12/16	28/12/16	28/12/16	28/12/16	28/12/16	
Sand (%)	29.36	30.24	43.25	28.44	13.31	Hydrometer
Clay (%)	32.76	45.08	27.84	51.27	65.84	
Silt (%)	37.88	24.69	28.91	20.29	20.85	
Texture Class	Clay loam	clay	Clay loam	clay	clay	
P^H-H_2O (1:2.5)	5.67	6.80	6.10	6.40	6.20	Probe method
EC(ms/cm) (1:2.5)	0.08	0.11	0.07	0.10	0.09	
Exch.Na(meq/100gm of soil)	1.41	1.08	1.21	1.08	0.97	Ammonium Acetate & Instrumental
Exch.K(meq/100 gm of soil))	0.24	0.72	0.43	1.12	0.43	
Exch.Ca(meq/100 gm of soil)	29.06	44.44	40.51	41.70	45.29	
Exch.Mg(meq/100 gm of soil)	9.41	13.67	13.65	13.62	12.63	
CEC(meq/100 gm of soil)	46.27	67.81	67.67	65.68	74.79	
Sum of Cations (meq/100gm of soil)	40.13	59.92	55.80	57.52	59.32	
Organic Carbon(%)	1.62	1.29	1.52	1.83	1.26	Walklay Black
Nitrogen (%)	0.23	0.16	0.21	0.25	0.15	Kjeldahl digestion
Available P(mg P_2O_5/kg soil)	62.51	106.21	48.13	83.33	30.71	Olsen
Available K(mgK_2O/kg soil)	83.85	363.66	138.09	458.26	147.59	Ammonium Acetate
Exchangeable Sodium %(ESP)	3.06	1.59	1.79	1.65	1.29	
Available Sulphur	0.47	0.15	0.26	0.23	0.19	KH_2PO_4 Extraction
Bulk Density(gm/cm^3)	1.63	1.73	1.79	1.80	2.47	Gravimetric
Particle Density (g/cm^3)	2.67	2.61	2.66	2.63	2.61	Volumetric

Remark:

Processed by
Date 18/01/17

Checked by
Date 18/01/17

Approved By
Date 18/01/2017

Appendix 4 Description of explanatory variables used in the logistic regression model

Category	Variable Label	Variable type	Description & Value label
Personal and household attributes	Age	Continuous	Age of household head (years)
	Education	Dichotomous	Education Level of HH head (1= if at least read write; 0= otherwise)
	Farm labor	Continuous	Full-time farming labor (numbers)
Plot level characteristics	Plot slope	Dichotomous	Perceived plot Slope (1 = Flat; 0= Sloppy)
	Plot size	Continuous	Size of the plot (Timad)
	Soil fertility	Dichotomous	perceived soil fertility status of farmlands (1= if perceived fertile; 0 otherwise)
	No. of plots	Continuous	Number of plots owned by one household/Land fragmentation (numbers)
	Plot dist.	Continuous	Distance to plot from the farmer's home (minutes of walking)
Socioeconomic Assets	livestock	Continuous	Livestock owned (TLU)
	Off-farm income	Dichotomous	participation in off- farm income (1= participated; 0 otherwise)
	Use of hire labor	Dichotomous	Use of labor other than family members (1 = yes; 0 otherwise)
	labour sharing	Dichotomous	Participation in labour sharing and assistance activities (e.g. Wenfel and Debo) (1= if yes; 0 otherwise)
Institutional support and Local cooperation	Access to land management advice	Dichotomous	Access to agricultural extension /Access to Technical advice and training (1= if get access; 0 otherwise)
	Credit access	Dichotomous	Access to credit e.g. fertilizer credit, credit from micro-finance institutions (1=if have access; 0 otherwise)
	Being within Project site	Dichotomous	Participation in SLM Program project (1 if participated, 0 otherwise)
	Participation in safety net program	Dichotomous	Participation in safety net program (1= participated; 0 otherwise)
	Incentives from the government	Dichotomous	incentives received from the government (1 = yes; 0 otherwise)
Perception of benefits, costs and Risk	Perception on the Importance SLM practices	Dichotomous	Awareness level on the importance SLM (1= if yes; 0 otherwise)
	Holding land use certificates	Dichotomous	Feeling in land certificates for land holding security (Trust on government's policy) (1= if secured; 0 otherwise)
	Expectation of drought incidence	Dichotomous	expecting drought and climate related hazards (1= if yes; 0 otherwise)

Source: Author's compilation, 2017